Hale-Bopp Brightens: Viewer's Guide Inside

ASTRONOMY®

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Are We Alone in the Universe?

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Comet Hyakutake Wrapup

- The Violence of Starmaking
- The Lagoon Nebula in 3-D

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MEADE

ETX

90mm Maksutov-Cassegrain

MEADE SUPER PLÖSSL 26
8x21mm
MEADE
MEADE

Complete with cordless, battery-powered motor drive; table tripod; and Series 4000 Super Plössl 26mm eyepiece:

$495

Now you can have the exquisite, diffraction-limited imaging and ultraportability of a 90mm Maksutov-Cassegrain...*at only $495, complete!*

Meade technology has just made it possible for you to own a telescope that, only a few years ago, would have cost over $2000.

The revolutionary Meade ETX™ goes anywhere with you at a moment's notice and presents the finest optical images—*bar none*—ever made available in an ultraportable telescope.

From its stunningly beautiful, deep-violet, polished-aluminum optical tube to its precision internal flip-mirror system, the ETX is as unprecedented for its fit and finish as for its breathtaking optical performance. For the casual or beginning observer, the Meade ETX may be all the telescope ever required. For the advanced observer who already owns a larger instrument, the ETX is the perfect ultraportable field telescope.

- **Optical System:** Manufactured entirely at the Meade Irvine facility, ETX Maksutov optics produce stellar diffraction images virtually identical to those of the finest apochromatic refractor. *Optical performance and resolution warranted to equal or exceed any Maksutov optics of similar aperture ever manufactured at any price, past or present.* Optics so high in contrast, image brightness, and resolution that the ETX consistently outperforms many telescopes of larger apertures.

- **Materials and Coatings:** ETX optics include a Maksutov corrector lens of Grade-A BK7 optical glass, individually matched to a hand-figured Pyrex® primary mirror. Meade Super Multi-Coatings on all optical surfaces maximize light transmission and image contrast.

Eyepiece-end of the ETX, showing Flip-Mirror Control, Focus Knob, R.A. Slow-motion and Lock, Dec. Slow-motion and Lock.

- **Cordless Motor Drive:** The cordless, internal motor drive system operates from three AA-size batteries that power the telescope for more than 50 hours. A North-South switch permits drive operation anywhere in the world.

- **Flip-Mirror System:** Flip the internal optical-flat mirror "up" for observing in the standard 90° position; flip the mirror "down" for terrestrial observing with the optional #932 45° Erecting Prism or for photography with the optional #64 Photo-Adapter.

Attach the optional #64 Photo-Adapter for through-the-telescope photography with your 35mm camera.

- **Equatorial Fork Mount:** Precise polar alignment in *seconds,* just by extending the center tripod leg to read your latitude on the leg's inscribed scale. Slow-motion controls in both R.A. and Dec. permit smooth manual tracking of terrestrial or astronomical objects; release the manual controls and automatic astronomical tracking is engaged through the motor drive.

- **Standard accessories** include a Meade Series 4000 Super Plössl 26mm eyepiece and 8 x 21mm *erect-image* viewfinder.

- **Optional accessories** include a Soft Carry Bag with shoulder strap (suitable for ETX hand-carry aboard an airplane); #64 Photo-Adapter; #932 45° Erecting Prism (standard with ETX Spotting Scope), and more than 20 eyepieces for powers from 31X to over 300X.

Use the optional #932 45° Erecting Prism for high-resolution terrestrial observing.

SPECIFICATIONS

ETX Astro Telescope—Includes Maksutov-Cassegrain optical tube assembly (D = 90mm, F = 1250mm, f/13.8) with EMC super multi-coatings; internal flip-mirror system for either straight-through or 90° observing position; equatorial fork mount with slow-motion controls, locks, and setting circles in R.A. and Dec; table tripod with elevation scale on center tripod leg; motor drive system with internal battery compartment accepting three (user-supplied) AA-size batteries; 8 x 21mm achromatic erect-image viewfinder; Series 4000 Super Plössl 26mm eyepiece (1.25"); operating instructions. *Net weight 9 lbs.*
$495 (+ $20 packing and shipping in the 48 states)

ETX Spotting Scope—Includes Maksutov-Cassegrain optical tube assembly (D = 90mm, F = 1250mm, f/13.8) identical to tube assembly of ETX Astro Telescope, with EMC super multi-coatings; internal flip-mirror system for either straight-through or 90° observing position; #932 45° erecting prism; 8 x 21mm achromatic erect-image viewfinder; Series 4000 Super Plössl 26mm eyepiece (1.25"); adapter block for attachment to standard (1/4-20) photo tripods; operating instructions. *Net weight 3 lbs.*
$395 (+ $10 packing and shipping in the 48 states)

Prices listed are suggested U.S. mail-order retail prices.

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July 1996
Vol. 24, No. 7

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Bob King

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The brightest comet in 20 years thrilled observers around the globe last March and April. Here its brilliant coma and magnificent tail brush the sky above the Red Rocks of Sedona, Arizona. *Joshua Vaughn.*

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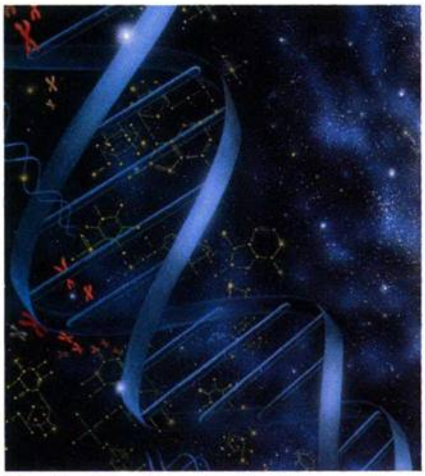

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BEHIND THE SCENES

The Sounds of Silence

"Don't shout in the jungle." A wise suggestion, especially when you're trying to determine who, or what, might be out there in the dark. Indeed, for over thirty years astronomers have adopted this strategy in their search for extraterrestrial intelligence (SETI). Radio telescopes are used as super ears rather than loudspeakers.

The results of three decades'-worth of intensive listening, however, have been less than fruitful. To date, only a few dozen suspect signals have been detected by the major SETI projects. Some of the stronger signals, intriguingly, emanated from the plane of the Milky Way, but none have been heard from again. Could the lack of obvious signs of intelligent life be telling us something fundamental? Even if we shouted at the top of our collective lungs, would there be any extraterrestrial ears out there to hear us? Are we alone?

Steven Ostro

Are We Alone?

Bob Naeye's feature article, "Ok, Where are They?" (see page 36) unabashedly explores this issue. Although SETI sympathizers may feel a bit miffed, I hope Bob's article is taken in the spirit in which it is intended: an intellectual exercise in weighing the value of negative results. I think most of us who look to the stars prefer to believe that life is abundant in the Galaxy. But the universe has a way of doing its own thing despite our expectations.

Whether or not a signal is ever detected, it is the search itself that forces us to keep our existence in a cosmic context. Imagine how a star-filled night would appear if we knew life was out there — or was not out there? The bottom line is that we have to search. Though it may be in vain, we have to search.

You may be wondering why Robert Burnham isn't writing this installment of "Behind the Scenes." Our editor has decided to pursue a freelance writing career. You will definitely see his byline in these pages in future issues. Robert, who has been associated with ASTRONOMY for nearly twenty years, will be sorely missed.

Sincerely,

Jeff Kanipe

Jeff Kanipe
Managing Editor
jkanipe@astronomy.com

LETTERS

A Beautiful Hypothesis, Baby

Michio Kaku's "Before the Big Bang" (May 1996) was fascinating. However, I was astonished by the comment, "Although there is no experimental proof for quantum cosmology, the theory is so compelling and beautiful that it has become the center of intense research." That line of reasoning would provide comic relief for a study section at the National Institutes of Health. Money is scarce enough that scientists with hypotheses that can be tested are not being funded.

I suspect that most ASTRONOMY readers are incapable of independently evaluating an idea like this. I also know that the science in your magazine is not refereed; all the more reason to take extra care to provide a balanced point of view, no? —*Stephen Sramek, Madison, Wisconsin, ssramek @waun.tdsnet.com*

(continued on page 16)

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Meade Pictor 1616XT images by Jack Newton: clockwise from upper left—Horsehead Nebula; M42; M51; M27.

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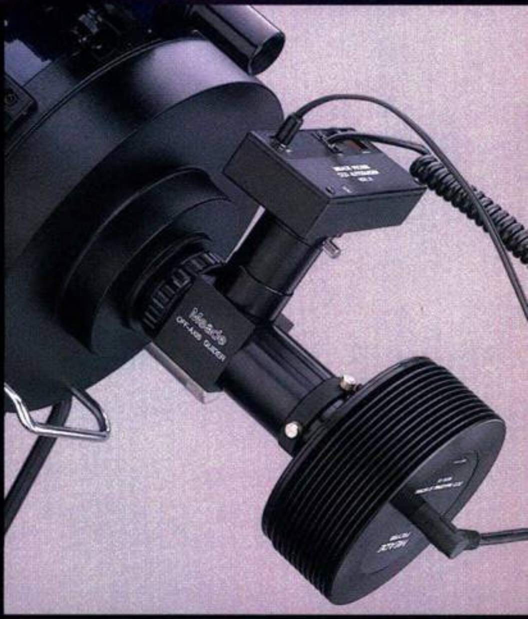
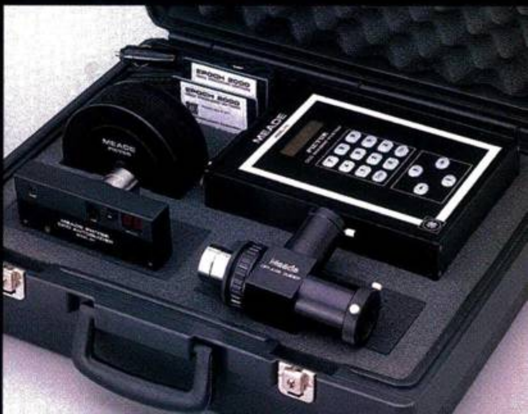


CCD imaging is **automatic** with a Meade Pictor Imager. And, for a limited time, when you purchase the Pictor 416XT at $2495 or the Pictor 1616XT at $6495, we'll pack it with the $800 Meade CCD Equipment System *(below)* **at no additional charge.** Use the Pictor 201XT and CCD Off-Axis Guider *(above)* to autoguide your Pictor 416XT or 1616XT—or your 35mm camera during astrophotography. No other autoguider/imager system is so flexible and so easy to use.



12"
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MEADE LX200 EMC
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MEADE LX200 EMC
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MEA

LX200

The largest-selling serious telescopes in the world.

In virtually every country in the world where serious telescopes are sold, more Meade LX200's are sold than all competing models ***combined***. Consider these *standard-equipment* specifications:

- **Superb Optics:** LX200 imaging capabilities are a legend in the industry; we regularly receive reports stating that optical performance approaches that of a fine *ED* apochromatic lens.
- **Automatic GO TO Capability:** Meade LX200's are *the only commercial telescopes ever manufactured* that automatically GO TO any input R.A. and Dec., or to any of over 64,350 objects in the onboard database, *to a precision of one arc-minute or better.*
- **Meade LX200 High-Precision Pointing**™ is so precise it permits the positioning of *every* selected object on *every* commercially-available CCD chip *every* time, automatically — *a feat that no other telescope priced under $40,000 can accomplish.*
- **Permanently-Programmable Smart Drive**™ routinely achieves 5 arc. sec. periodic error, an observatory standard.
- **9-Speed Dual-Axis Electronics:** Electronics that cover every possible contingency of telescope positioning—from 2x photo-guide, to 32x image centering, to 8°/sec. slewing across the sky, as well as 6 other dual-axis drive speeds in between.
- **Field Operation:** No other telescopes of such incredible capabilities transport so readily for field operation. The optional #1812 Electronic DC Adapter (a compact 4 oz. unit) allows for field powering directly from an auto cigarette lighter plug.

SPECIFICATIONS: 7", 8", 10", and 12" LX200's—Each complete telescope includes 8" or 10" (f/6.3 or f/10) or 12" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty fork mount with 4" polar ball bearing, dual-axis 5.75" worm gears, and multi-function control panel; manual and electric slow-motion controls on both axes; keypad hand controller with digital readout display, permanently programmable Smart Drive, 9-speed drive controls on both axes (7-speed on 12"), High-Precision Pointing, and GO TO controller; 64,359-object onboard celestial software library; 25 ft. power cord and adapter for telescope operation from 115v.AC; 8 x 50mm viewfinder; 1.25" diagonal prism (7", 8", 10") or 2" diagonal mirror with 1.25" adapter (12"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (7", 8", 10") or giant field tripod (12"); complete operating instructions.

8" LX200 Schmidt-Cassegrain	**$2795.**
10" LX200 Schmidt-Cassegrain	**3195.**
12" LX200 Schmidt-Cassegrain	**4495.**
7" LX200 Maksutov-Cassegrain	**3295.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 12"—$215; 7"—$125.

ADE

LX50

Advanced technology at the most affordable prices ever.

- **Battery-Powered, Completely Cordless Operation!** Meade LX50 models operate for more than 50 hours from six AA-size batteries inserted through the telescope's control panel. Or use the standard-equipment 25 ft. cord to power the telescope directly from any auto cigarette lighter plug.

- **Standard-Equipment Declination Motor and Hand Controller:** Plug the hand controller into the LX50 control panel and you're ready for full dual-axis drive capability at any of 4 photo-guide or microslew speeds: 2x, 8x, 16x, or 32x, plus quartz-controlled sidereal-rate tracking in R.A. Switch speeds instantly using the speed-control button on the hand controller. Dual-axis drive rate is indicated by a red LED.

- **Multi-Function Control Panel:** Includes connectors for CCD autoguiders; for the standard-equipment Declination motor; and for the optional Magellan II Computer-Corrector *(below)*. A North-South switch permits telescope operation anywhere in the world.

- **Super Multi-Coated Optics:** The exact same EMC super multi-coated optical tube assemblies included with Meade LX200 models.

- **Massive LX200-type Fork Mounts:** Meade LX50 mounts are manufactured of the same virgin aluminum castings as Meade LX200 Schmidt-Cassegrains. Massive, rigid mountings that include the Meade LX worm-gear drive system with low periodic error for advanced photographic or CCD imaging applications. *No competing mid-priced equatorial mountings even come close.*

LX50 models shown with optional Field Tripod.

SPECIFICATIONS: 7", 8", and 10" LX50's—Each complete telescope includes 8" or 10" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty LX200-type fork mount; 5.75" LX worm gear system in R.A.; multi-function control panel; DC servo Declination motor; manual and electric slow-motion controls on both axes; setting circles on both axes; keypad hand controller; 4-speed drive controls on both axes; battery compartment accepting six (user-supplied) AA-size batteries; 25 ft. power cord for telescope operation from 12v. auto cigarette lighter plug; 6 x 30mm (7" and 8" models) or 8 x 50mm (10") viewfinder; 1.25" diagonal prism; MA25mm multi-coated eyepiece (1.25"); standard equatorial wedge with elevation scale, bubble level, and azimuth control; complete operating instructions.

8" LX50 Schmidt-Cassegrain	**$1395.**
10" LX50 Schmidt-Cassegrain	**1695.**
7" LX50 Maksutov-Cassegrain	**1795.**
Variable-Height Field Tripod	**295.**
7" Maksutov-Cassegrain Tube Ass'y, only	**1195.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 7"—$125; 7" Tube Assembly—$65.

Meade Magellan™ II Computer-Corrector for LX50 Telescopes: Plug the Magellan II into the control panel of your LX50 and enjoy an incredible range of advanced capabilities. ■ Fast manual slewing to any object, either from input RA and Dec or from the 12,218-object database. ■ High-resolution 4096-pulse encoders (5.3 arc-minute precision), completely concealed in special LX50 encoder compartments. ■ Quick 2-star alignment. ■ Large 32-character, red-backlighted display. ■ 4-speed (2x, 8x, 16x, 32x sidereal) dual-axis drive corrector/microslewing system.

#2024: Magellan II for LX50's—Includes Magellan II hand controller *(right)*; encoders for both axes; all required mounting hardware. Installs to any LX50 in minutes. **$495.** + $15 packing and shipping in the 48 states.

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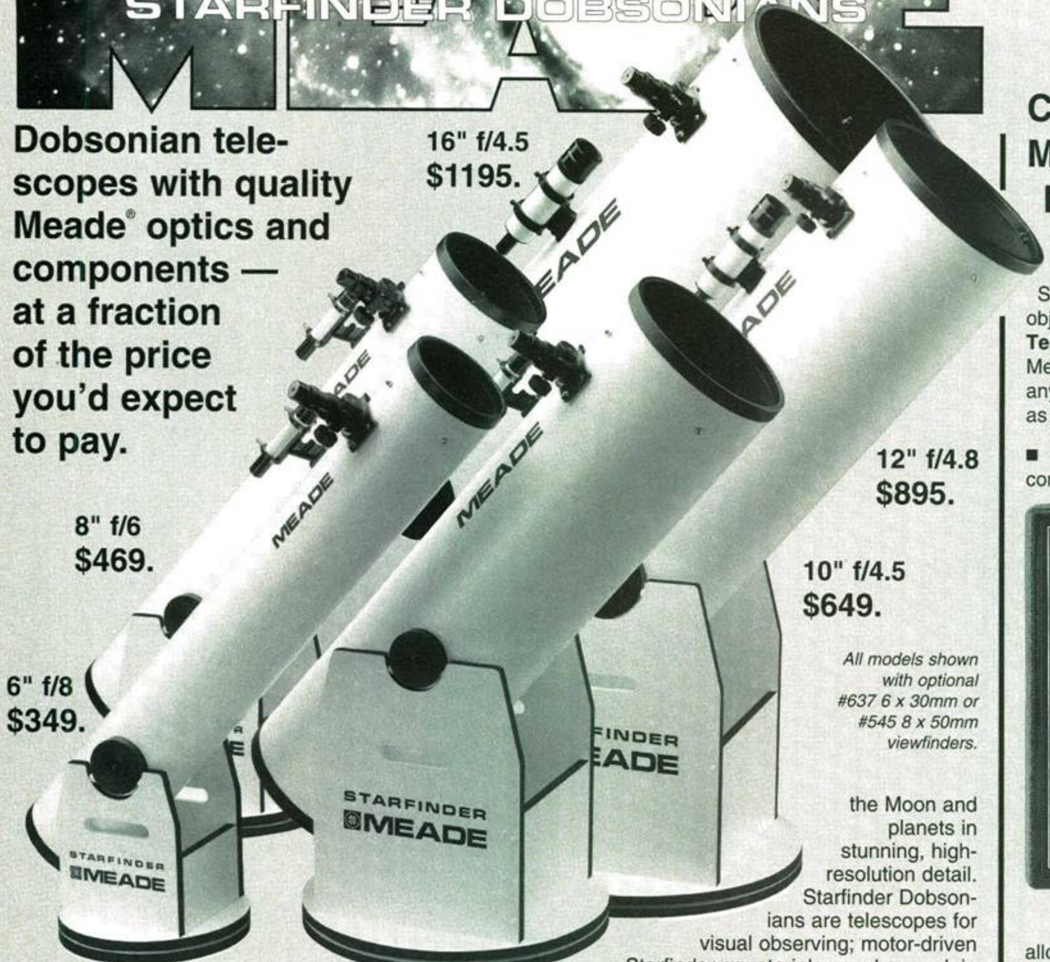

All models shown with optional #637 6 x 30mm or #545 8 x 50mm viewfinders.

Compare *feature-for-feature* with other similarly priced Dobsonians!

■ **Primary and Secondary Mirrors of Low-Expansion Pyrex® Glass:** Unlike the plate glass optics of other Dobsonians that can become thermally unstable (especially in larger apertures), Meade Dobsonians are made of Grade-A, fine-annealed Pyrex—the exact same professional-quality optics used on Meade Starfinder Equatorials.

■ **Precision Components:** Including a full-size rack-and-pinion focuser (1.25") with 2.6" travel and fully-adjustable *4-vane* secondary mirror system.

■ **Rigid, Durable, Beautiful Dobsonian Mountings**, manufactured of cabinet-quality materials, provide extremely smooth motions of the telescope in both altitude and azimuth. Both telescope axes ride on zero-backlash Teflon/Nylon bearings, facilitating the location and tracking of celestial objects.

■ **Optical Tubes:** Starfinder Dobsonians include the same strong, spiral-wound optical tubes used on Starfinder Equatorials *(right).* All telescopes include a multi-coated MA25mm eyepiece; each tube is factory pre-drilled for the optional 6 x 30mm or 8 x 50mm viewfinder.

■ **Performance!** A Meade Starfinder Dobsonian or Equatorial opens up the skies to an extremely wide range of serious visual observing: all 110 Messier objects, thousands of NGC objects—nebulae, galaxies, star clusters, in all their variations of form, color, and extent, as well as the Moon and planets in stunning, high-resolution detail. Starfinder Dobsonians are telescopes for visual observing; motor-driven Starfinder equatorials may be used, in addition, for lunar and planetary photography and even for limited deep-space photography.

Packing and UPS Shipping Charges to any address in the 48 states: 6"–$39; 8"–$49; 10"–$69; 12.5"–$79. 16"–$45 packing, shipped truck freight collect.

ACCESSORY OFFER!

At the time you order any Meade Dobsonian, you can buy 2 additional multi-coated eyepieces, MA9mm and 12mm, *and* the Meade #637 6 x 30mm viewfinder with metal bracket for a **total of $49.95!** *Purchased separately, the 2 eyepieces and viewfinder sell for $125.85!* Offer valid until further notice.

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Spend your time **observing, not searching** for objects! **With the incredible Meade Magellan™ Telescope Computer System** attached to your Meade Starfinder Dobsonian or Equatorial, finding any of **12,218 celestial objects** is almost as easy as pointing the telescope.

■ Don't spend $400, $500, or $600 for a computer system with fewer features! Designed and manufactured at the Meade Irvine facility, the Magellan I includes one of the largest object databases available, incorporates only premium-grade components, and sells for a low $295!

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NEXT
ON
MAGELLAN I
TELESCOPE COMPUTER SYSTEM
U.S.A.

Actual Size: 4" x 5" x 1.25"

■ **Easy to Use!** Just input the R.A. and Dec. of the object you wish to observe, or call up an object from Magellan's massive database. Magellan allows you to slew the telescope manually to the object and place it in the visual field, quickly and precisely.

■ **Fast 2-Star Alignment:** Point the telescope at 2 bright stars selected from the star database, and the computer is aligned in *seconds.* No need to input time or date, latitude or longitude. Magellan's powerful microprocessor calculates telescope position in milliseconds and directs your movements of the telescope for fast, accurate object location.

Meade Magellan II Computer-Corrector for Starfinder Equatorials

Plug the Magellan II into the control panel of your Meade DC-powered Starfinder Equatorial *(right)* and you have *all the capabilities of the Magellan I (above)* ***plus*** a 4-speed, dual-axis, drive-corrector/microslewing system!

Includes: Magellan II hand controller *(right)* with 4 dual-axis speed rates (2x, 8x, 16x, 32x sidereal); high-resolution 4096-pulse encoders for both axes; electric Declination control system; 12,218-object computer database; 2-star alignment; RS-232 serial interface. (For Meade *DC-powered* Starfinder Equatorials, only.)

#2018: for Starfinder Equatorial
6", 8", or 10" . . . . $495.
#2019: for Starfinder Equatorial 16" . . . 595.

Prices plus $20 packing & shipping in the 48 states.

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■ **High-Resolution 4096-pulse Encoders:** Each Magellan system includes two premium-grade, high-resolution encoders. Encoder precision is 5.3 arc minutes.

■ **Large 32-Character LCD Red-Backlighted Display:** The same LCD display included with the Meade LX200 hand controller. Includes variable illumination from dim to bright.

■ **12,218-Object Database:** A database that includes an amazing array of objects:

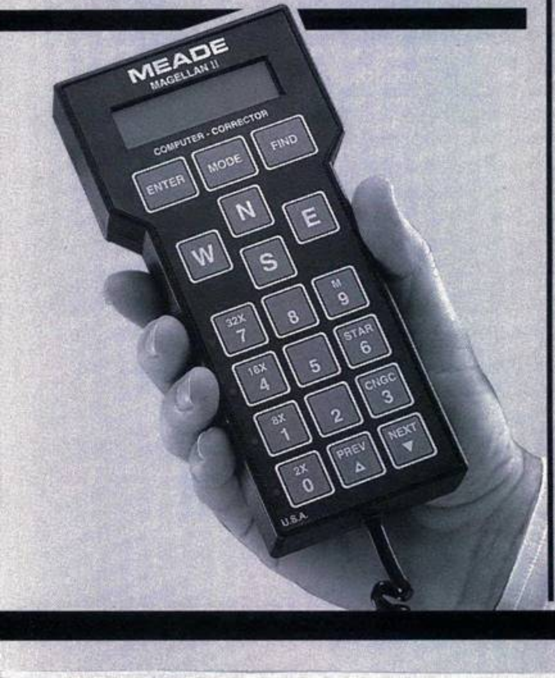
7,840	NGC objects; the complete NGC catalog
4,093	IC objects from the Index Catalog
125	user-defined objects
110	Messier objects; the complete catalog
42	alignment stars for the Magellan system
8	major planets, from Mercury to Pluto
12,218	objects, total

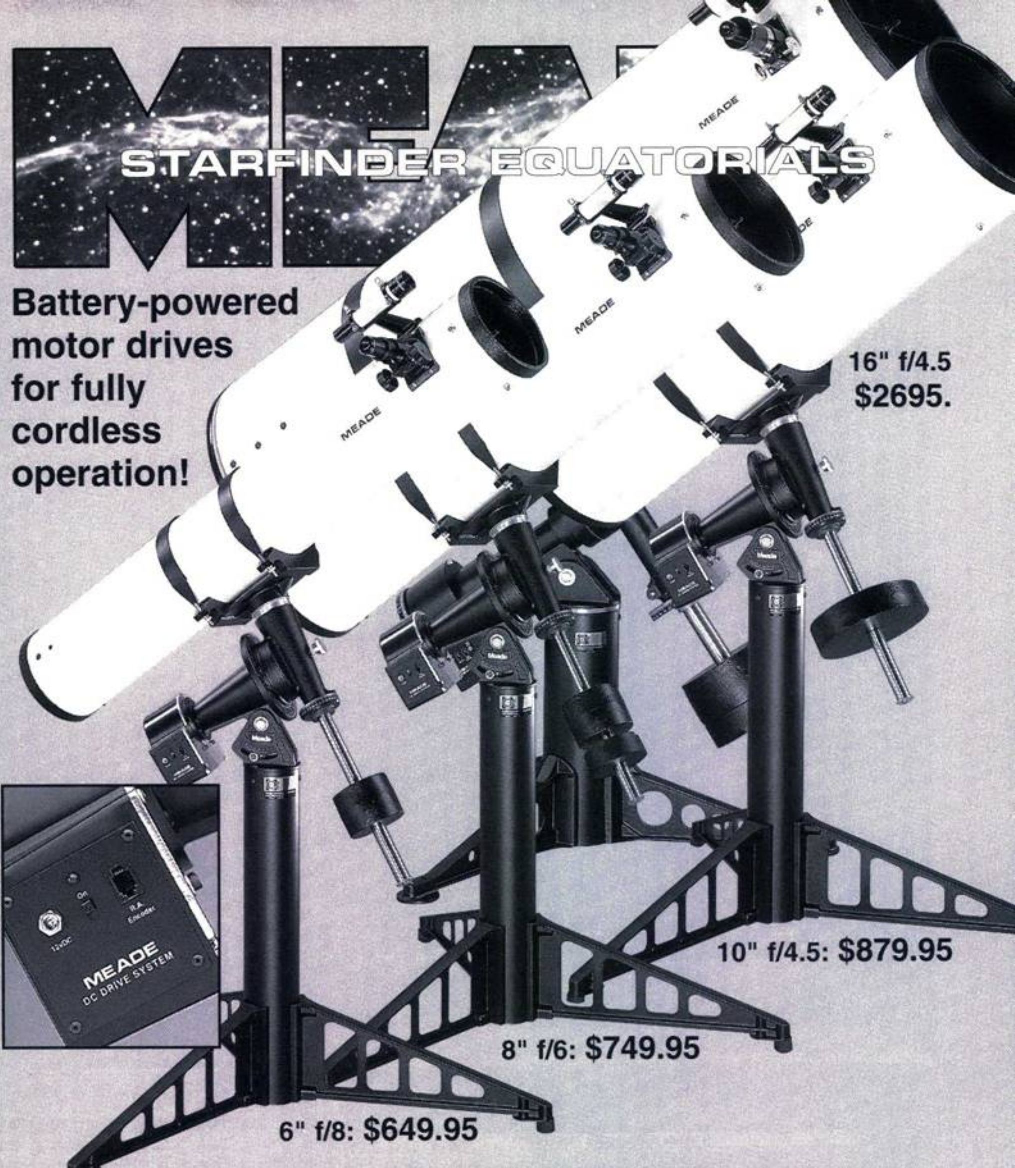
■ **Supplied Complete!** With other computers you pay *once* for the basic controller and then pay *again* for the "Encoder Installation Package." Meade Magellan Systems are supplied **complete** with: controller/display unit (4" x 5" x 1.25"); encoders for both telescope axes; RS-232 serial interface; bracket for convenient placement of the controller on the telescope tube; and attachment hardware. Just add the user-supplied 9v. transistor radio battery, and Magellan is ready to use. First-time installation is quick and simple.

Meade Magellan I
Telescope Computer Systems

#2010:	**for Meade Starfinder Dobsonian 6", 8", 10", 12.5", or 16"**	**$295.**
#2011:	**for Meade (DC-powered) Starfinder Equatorial 6", 8", or 10"**	**295.**
#2012:	**for Meade (DC-powered) Starfinder Equatorial 16**	**295.**

All prices plus $15 packing & shipping in the 48 states. Prices shown are suggested U.S. national mail-order retail prices. For additional information on Meade Magellan systems, send for your free copy of **Meade Bulletin 2900.**





STARFINDER EQUATORIALS

Battery-powered motor drives for fully cordless operation!

16" f/4.5 $2695.

10" f/4.5: $879.95

8" f/6: $749.95

6" f/8: $649.95

Standard equipment on 6", 8", and 10" equatorial models includes:

■ **Superb Optical System:** Includes hand-figured, parabolic primary mirror and elliptical flat secondary, both of Grade-A Pyrex glass. Optics are multi-coated and meet the theoretical limits of resolution.

■ **Precision Equatorial Mount:** Manufactured of machined aluminum to tolerances of .001" or better, with 4"-dia. pier and die-cast tripod legs for rock-solid support of the optical tube. Moves effortlessly from object to object on precision bearing surfaces. Polar and Dec. shafts are 1" solid steel. Setting circles on both axes.

■ **Battery-Powered Cordless Drive System!** Provides fully automatic tracking of celestial objects. Operates for more than 50 hours from 6 (user-supplied) AA-size batteries inserted through the drive cover. Control panel *(see inset photo, above)* also permits powering of telescope from 12v. auto cigarette lighter plug, using optional 25' cord.

■ **Accessories and Components:** Rack-and-pinion focuser (1.25") with 2.6" travel; #637 6 x 30mm viewfinder; multi-coated MA25mm (1.25") eyepiece; strong, durable, spiral-wound optical tube with attractive white finish.

■ **Starfinder Equatorial 16:** Includes equatorial mounting with 1.5" steel shafts, Sealmaster ball bearings, 6"-dia. pier, 6 x AA-size battery-powered worm gear drive, 8 x 50mm viewfinder, #682 giant (2" & 1.25") rack-and-pinion focuser.

Packing and UPS Shipping Charges to any address in the 48 states: 6"–$65; 8"–$75; 10"– $90. 16"–$55 packing, shipped truck freight collect.

To Order: Contact your authorized Meade Advanced Products Dealer. All prices shown are suggested USA mail-order retail prices.

Meade 1996 General Catalog, $3.00 postpaid, is available from your authorized Meade dealer or directly from Meade Instruments.

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At the time you order any Meade Starfinder Equatorial Telescope, you can buy 2 additional multi-coated eyepieces, MA9mm and 12mm, for a **total of $29.95!** *Purchased separately, the 2 eyepieces sell for $75.90!* Offer valid until further notice.

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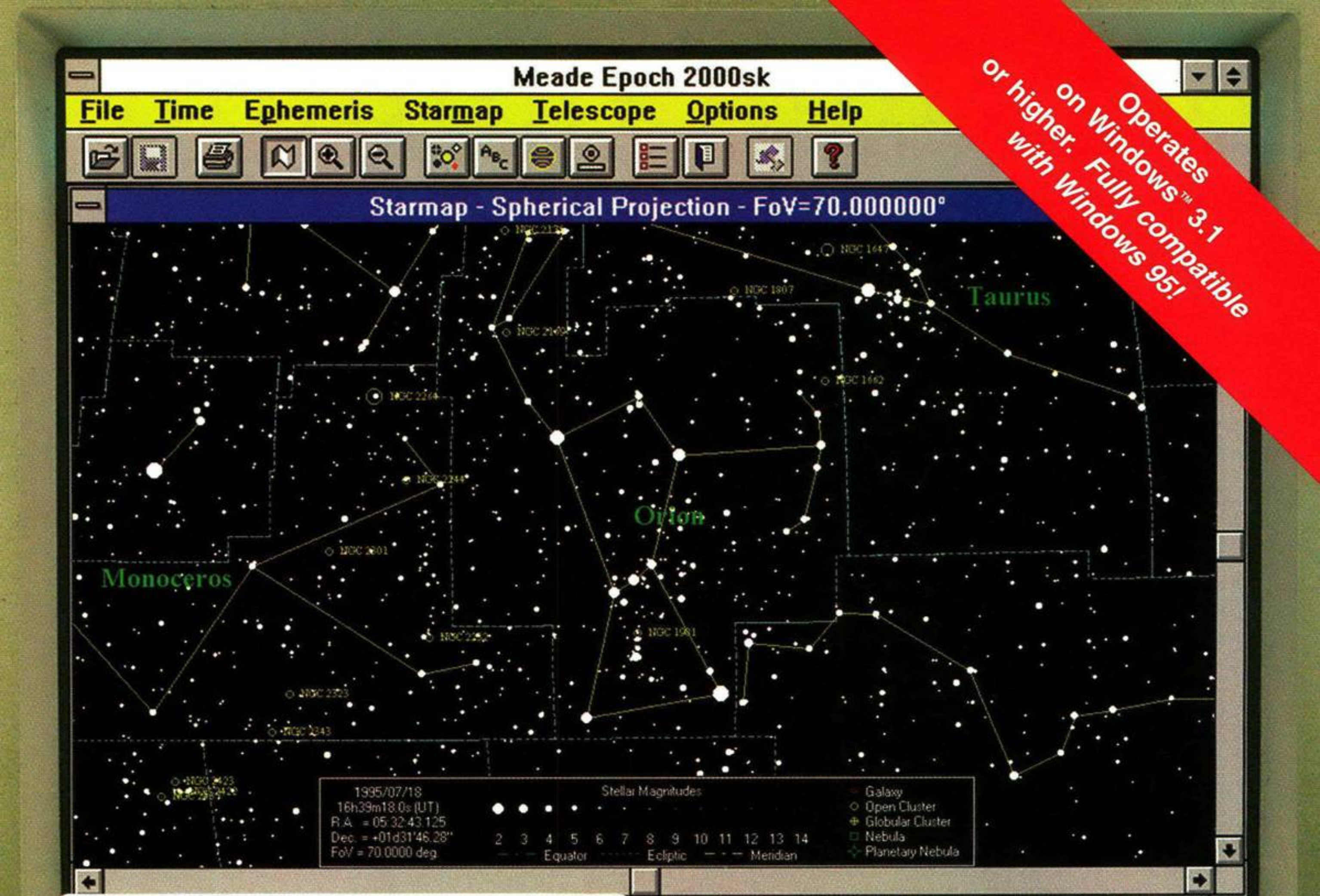
Meade Epoch 2000sk
File
Time
Ephemeris
Starmap
Telescope
Options
Help
Starmap - Spherical Projection - FoV=70.000000°
Taurus
Orion
Monoceros
NGC 2175
NGC 1647
NGC 1807
NGC 2169
NGC 1662
NGC 2264
NGC 2244
NGC 2301
NGC 1981
NGC 2232
NGC 2323
NGC 2343
NGC 2423
1995/07/18
16h39m18.0s (UT)
R.A. = 05:32:43.125
Dec. = +01d31'46.28"
FoV = 70.0000 deg
Stellar Magnitudes
2 3 4 5 6 7 8 9 10 11 12 13 14
Equator
Ecliptic
Meridian
Galaxy
Open Cluster
Globular Cluster
Nebula
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15:32:34
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Help
Scale Image
1995/07/13
Loc. 15:23:32
x,y = 298,164
Dn = 233,233

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Series 4000™ 2x Apochromatic Barlow Lens

#140: The most advanced Barlow lens available for commercial telescopes, the Meade #140 includes 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images absolutely unmatched in resolution, contrast and color correction. The #140 optically complements any telescope — refractor, reflector, or Schmidt-Cassegrain. Accepts 1.25" eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 26mm.

$79.95 (4.27)

Series 4000™ Super Plössls
52° field; multi-coated

Meade 4-element Super Plössls, updated and redesigned to utilize the latest in optical glass-types, are the finest general-purpose eyepieces available. For observing hairline lunar and planetary detail, splitting close doubles, or for deep-space; guaranteed to deliver more contrast and image sharpness than any other brand. Rubber eyeguards fold down for eyeglass wearers–a feature not available on competing brands. Multi-coated. All focal lengths through 32mm are parfocal.

Super Plössls (SP; 4-elements; 1.25"; 52°):

6.4, 9.7, 12.4, 15, 20, 26mm	each:	**$79.95** (3.45)
32mm (52°); **40mm** (44°)	each:	**99.95** (3.79)
56mm (52°; 2")		**199.95** (5.48)

Series 4000™ Super Wide Angle
67° field; multi-coated

For exquisite wide-angle images at low-to-medium powers, with pinpoint edge-of-field resolution. Ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8mm, 18mm, and 24.5mm are superb complements to the #140 Barlow, above.

Super Wide Angle (SWA; 6-elements; 1.25"; 67°)–**13.8mm: $139.95** (3.94); **18mm: 149.95** (3.94); **24.5mm: 179.95** (4.68); **32mm** (2"): **239.95** (5.87); **40mm** (2"): **299.95** (6.28)

Series 4000™ Ultra Wide Angle
84° field; multi-coated

The ultimate eyepieces; extreme image sharpness over an amazing 84° field. A perfect optical match with Schmidt-Cassegrains and fast Newtonians.

Ultra Wide Angle (UWA; 8-elements; 1.25"; 84°)– **4.7mm: $169.95** (3.94); **6.7mm: 199.95** (3.94); **8.8mm** (1.25"/2"): **239.95** (5.87); **14mm** (1.25"/2"): **299.95** (6.28)

World's Most Advanced Illuminated Reticle Eyepiece

Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Multi-coated optics. **Internal batteries included.** Bullseye reticle. 1.25".

$149.95 (3.45)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator.

$129.95 (3.45)

Series 3000™ Plössls
50° field; multi-coated

The very latest in eyepieces from Meade optical designers, new Meade Series 3000 Plössls yield the finest image corrections obtainable from the classical 4-element Plössl design. Available in a wide range of focal lengths from 5mm through 25mm. All five eyepieces are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössls, Meade Series 3000's are **multi-coated** for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters. Manufactured exclusively for Meade Instruments by one of Japan's leading lensmakers, Series 3000 Plössls produce fine, high-resolution results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

Series 3000 Plössls (4-elements; 1.25"; 50°)
5, 6.7, 9.5, 16, 25mm each: **$49.95** (3.45)

Series 4000™ f/6.3 Focal Reducer/ Field Flattener

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5" at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture.

$129.95 (3.60)

Series 4000 Photo-Visual Color Filters (1.25")–Premium filters, made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

#8 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue

each **$14.95** (2.29)

Set #1–4 filters: #12, #23A, #58, #80A	**49.95** (2.98)
Set #2–4 filters: #11, #25A, #47, #82A	**49.95** (2.98)
Set #3–4 filters: #8, #21, #38A, #56	**49.95** (2.98)

Series 4000 Moon Filter (#ND96): Reduces glare and irradiation during lunar observing. 13% uniform light transmission across the visual spectrum. Threads into 1.25" barrels. **$16.95** (2.29)

#911B
#910B
#908B
#911N
#910N
#908N

Series 4000 Nebular Filters—Premium multi-layer interference filters, the finest obtainable. Use broadband ("B") filters to block most forms of light pollution; use narrowband ("N") filters in heavily light-polluted areas or for extremely high-contrast observing of faint nebulae.

#908B–Threads into 1.25" eyepieces, 26mm dia.	**79.95** (3.45)
#910B–Threads into 2" eyepieces, 44mm dia.	**119.95** (3.85)
#911B–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**99.95** (3.94)
#908N–Threads into 1.25" eyepieces, 26mm dia.	**89.95** (3.45)
#910N–Threads into 2" eyepieces, 44mm dia.	**129.95** (3.85)
#911N–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**119.95** (3.94)

Series 3000™ Plössl 40mm 44°

An excellent complement to the Series 3000 Plössls above, this all-new Plössl 40mm produces spectacular low-power, wide-field results with any telescope. Includes classical 4-element Plössl optics, **multi-coated.** Barrel dia. 1.25"; threaded for filters. Apparent field: 44°.

$79.95 (3.79)

2x Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25"

$47.95 (3.45)

#905 Variable Polarizer (1.25")

For glare reduction in observing the Moon. Includes two Polarizer filters mounted in a machined cell and permits continuously variable light transmission from 5% to 25%, to compensate for varying lunar surface brightness according to the Moon's phase and the aperture of the telescope. Accepts 1.25" eyepieces. **$49.95** (4.27)

2x Short-Focus Barlow (1.25")

#126: Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, above. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated. **$47.95** (3.45)

Modified Achromatic Eyepieces

Meade 3-element MA eyepieces yield sharp, well-corrected images on the Moon, planets, and deep-space at a reasonable price. Multi-coated; threaded for filters; 1.25" barrel diameter. Apparent field: 40°. **MA 9, 12, 25, 40mm.**

each: **$37.95** (3.45)

MA12mm Illuminated Reticle Eyepiece

Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle. Wireless red LED illuminator and variable brightness control. 1.25" **Batteries included.** **$99.95** (3.45)

As above but with 6 ft. cord and plug for Meade telescopes with power panels, in place of wireless illuminator. **$79.95** (3.45)

2x-3x Variable Barlow (1.25")

#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25".

$59.95 (3.45)

Camera Adapters

Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.

.965": **$27.95**; 1.25": **$29.95** (2.98)

Variable-Projection Camera Adapter (1.25")

Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-mount for your camera.

$39.95 (2.98)

2" Diagonal Mirror

#929: Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes multi-coated precision optical flat made at the Meade factory; with 1.25" eyepiece adapter. **#930:** Same as #929 but with 2" barrel to fit into focusers with 2" eyepiece-holders.

#929 or **#930**, each: **$99.95** (5.87)

Variable Tele-Extender

For eyepiece-projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Sliding cell with lock permits wide range of projection magnifications with the same eyepiece. Use with T-mount for your camera.

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45° Erecting Prisms

Fully coated roof prisms to invert the astronomical image in Schmidt-Cassegrains or refractors during terrestrial observations, while presenting a convenient 45° observing angle. Specify **#927** (.965"), **#928** (1.25"), or **#931** (fits .965" focuser, accepts 1.25" eyepieces).

$42.95 (3.45)

T-Adapters for SCT's

Rigidly couples camera to telescope for prime focus photography with any Meade or Celestron Schmidt-Cassegrain. Use with T-Mount for your 35mm camera.

$26.95 (2.98)

HOW TO ORDER

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■ Suggested shipping and handling charges to the 48 states by U.P.S. or U.S. Mail shown in ( ) next to each price.

■ Meade accessories may be ordered from any Meade Advanced Products Dealer. **The following national mail-order dealers carry all Meade accessories in-stock for immediate shipment:**

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Orders: 800-245-7963; Info.: 603-742-4888.

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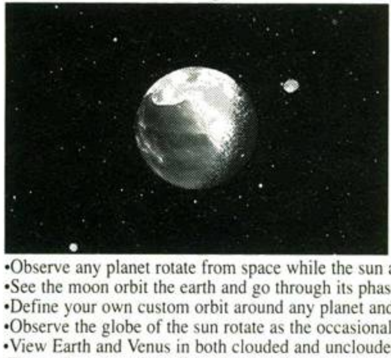

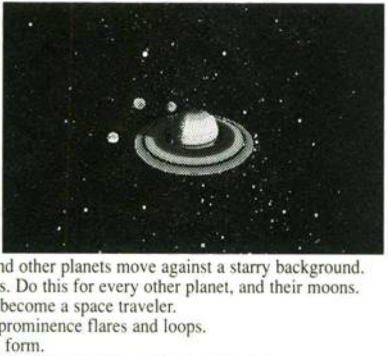

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LETTERS

The problem is that Kaku is confusing the philosophical term "nothing" (God created the universe from nothing) with the physical nature of empty space. As recent articles in other scientific journals have pointed out, empty space is not without an underlying, perhaps superstring structure. Thought experiments demonstrating that the universe is somehow relating to its underlying structure do not bring us any closer to answering the schoolchild's question, "Where does the structure come from?" — *Peter Gaffney, Astoria, New York, peterjmg@msn.com*

In summary, the essence of the article is: zero equals one. I would sooner believe in a flat or hollow Earth or that fighting angels created craters on the Moon. Science is a progressive analysis of the facts — not a warm and fuzzy. — *Dale Franklin, Houston, Texas, dale_franklin@crow.bm c.com*

— *Michio Kaku responds: money is scarce enough without pitting scientists at the National Science Foundation against those at the National Institutes of Health! A more "balanced" point of view would require presenting alternative theories in the scientific literature about where the Big Bang came from. Unfortunately, there are none.*

Nothing and "empty space" are two entirely different things: space refers to a bubble, a four-dimensional manifold described by Einstein's theory. However, these bubbles are floating in a larger arena, which is the nothing I am referring to.

Black holes, predicted by general relativity, were once thought to be as silly as a hollow Earth. Now we have discovered about 12 of them in space. There is nothing warm and fuzzy about the foundations of quantum cosmology, unless the reader thinks general relativity and quantum mechanics are warm and fuzzy.

Pluto Not a Planet?

Perhaps as a counterpoint to the March 7, 1996, press conference where the latest HST images of Pluto were released, several newspapers and television news broadcasts ran pieces on what they termed a "scien-

(continued on page 20)

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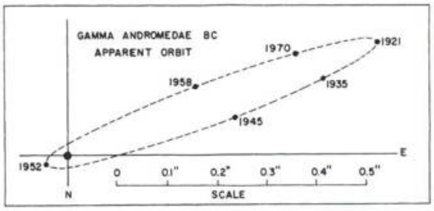

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LETTERS

tific debate" over whether Pluto should really be classified as a planet. As a planetary scientist who has studied Pluto and its sibling Triton for the past eight years, I feel the answer should be a resounding "yes."

First, Pluto formed in and remains in a direct solar orbit. This is the simplest definition of a planet, and is the reason that asteroids are frequently referred to as "minor planets."

Second, Pluto is large enough that forces due to its self-gravity exceed the strength of the materials of which it is composed, resulting in a spherical shape. This is an important physical criterion for defining a planet.

Third, Pluto has a significant atmosphere and a moon, Charon, which formed in Pluto orbit. Other "undisputed" planets do not possess these traits (Mercury lacks a significant atmosphere and moons, Venus and Mars lack moons that formed around them). While this is not central to the definition of a planet, it is nevertheless suggestive that Pluto is appropriately classified as one of the major planets of the solar system. — *John A. Stansberry, Lowell Observatory, Flagstaff, Arizona*

Multiple Strike Stricken

Your article "Multiple Impact on Earth by Asteroid or Comet String" (AstroNews, April 1996) is an example of poorly researched science. I've studied Hicks Dome in Hardin County, Illinois. I also sought commentary on Rampino and Volk's work from Allen V. Heyl, a retired U.S. Geological Survey geologist who has visited and analyzed every crypto-explosive structure listed in the article. Rampino and Volk did not carefully use the literature.

According to Heyl, only Crooked Creek, Decaturville, and Weableau are impact structures. They may have formed from a small asteroid or comet string. The other structures are not impact related. Three other structures in Kentucky were not mentioned by Rampino and Volk, and they are aligned with the eight structures mentioned. They are the Muldraugh Dome, near Fort Knox; the

Jeptha Knob structure, near Shelbyville; and the Versailles structure, near Versailles. — *Alan Goldstein, Falls of the Ohio State Park, Clarksville, Indiana, deepskyspy@aol.com*

The Day the Dinosaurs Died

Regarding your very interesting article "The Day the Dinosaurs Died" by Ron Cowen (April 1996), I have some comments. First, there's no way to deny that geologically recent impacts have occurred — just look at the Moon. If craters like Tycho occurred on the Moon, they also occurred on Earth.

Second, the statistics on Earth-crossing asteroids and their predicted impact rates add fuel to the fire; many devastating impacts have occurred and will occur with average intervals measured in hundreds of millions of years.

Third, suppose fossils of microorganisms are observed through the K-T boundary. Does this mean the impact had no effect on them? Of course not — it simply means they may have been reduced to fractions of their original populations. Because their food needs were small, they stood a good chance of returning in large numbers. With large animals, the chances of surviving would be slim because their food supply would be greatly reduced. — *James C. LoPresto, Edinboro University, Edinboro, Pennsylvania, lopresto@edinboro.edu*

Corrections

In "The Giant Holes of the Moon" by Paul D. Spudis (May 1996), the photo of the Orientale Basin on page 50 was flopped left-right.

Orders for Patrick Stewart's video From Here to Infinity (New Products, March 1996) should be sent to Right Side Up Video, 15071 Keswick Street, Van Nuys, CA 91405, phone (818) 785-0101. ☐

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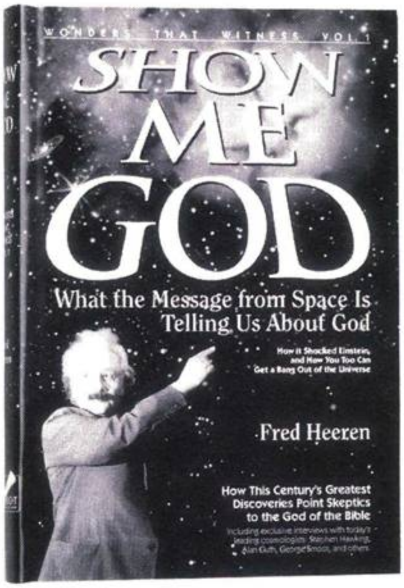
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ASTRO FORUM

Springtime for Hyakutake

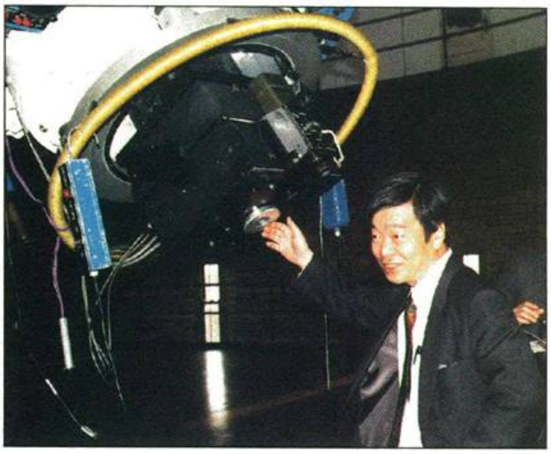
by John Shibley

31 March 1996

Through these squeaky doors and into this very hallway have walked the likes of Edward Emerson Barnard, George Ellery Hale, Albert Einstein, and Edwin Hubble. They came to partake of the Yerkes Observatory and its massive 40-inch f/16 refractor, the Space Telescope of its time and still the world's largest refractor. But this premier instrument frequently suffers the fickles of Wisconsin weather. Yerkes director Hale realized this shortly after the observatory was dedicated in 1898, and subsequently poured his efforts into building an observatory out in California. Tonight, as if Hale's ghost is saying "I told you so . . .," the weather is cloudy, cool and damp. It's even starting to drizzle. But that doesn't matter to me, for come clear or cloudy weather I'm going to meet Yuji Hyakutake, discoverer of this past spring's spectacular comet. And if it clears off, we'll observe his namesake through the 40-inch refractor. He and I can only hope.

October 1965

Yuji Hyakutake gets his astro bug one chilly morning in 1965 as the brilliant comet Ikeya-Seki rises tail-first above the eastern horizon. At that precise moment, 15-year-old Yuji realizes that astronomy is for him. What area of astronomy, he isn't sure. (Maybe comets?) Recently he read an introductory astronomy book with pictures of an observatory in America, the Yerkes Observatory with its 40-inch refractor, the largest in the world. Maybe someday he'll look through it at a comet like this. Maybe, he muses, he will even discover a comet as spectacular as the one he's watching now. The likelihood of these two farfetched events actually happening makes him chuckle.



ASTRONOMY: John Shibley

31 March 1996

A bus lumbers into the observatory's driveway bringing passengers from Chicago. Through the din of formal introduction I meet Hyakutake for the first time: a shy, unassuming middle-aged man who looks a bit worse for the wear due to jet-lag and the demands of meeting people for three days. Yuji Hyakutake has been seeing Chicago up close, attending star parties and signing autographs under the able auspices of Chicago's Adler Planetarium. This is his first trip out of Japan, and he's exhilarated but dead tired. What's all the excitement over me? he asks. After all, it's the comet that's doing all the work, he points out. Suddenly he's that teen on a long-ago October morning. This is Yerkes with its 40-inch. And it's beginning to clear.

July 1965 through July 1994

With all the enthusiasm and energy of a kid with purpose, Hyakutake sets about learning astronomy with his dad, even going so far as to grind a mirror for his first scope, an 8-inch f/6. But as with most burgeoning amateurs, the onslaught of early adulthood means responsibilities of college, followed in short order by the demands of family and a career. Through the years a vision of Ikeya-Seki rising like a predawn searchlight keeps his passion for comets alive.

Finally in 1989, armed with a 4-inch Takahashi refractor, Hyakutake mounts a comet search in earnest. One problem immediately becomes apparent: persistent light pollution around his hometown. The solution? Pack up the family, change jobs, and relocate to southern Japan, where light pollution has yet to rear its ugly head. In 1994 he does just that.

31 March 1996

Rising before Yuji Hyakutake is this 90-foot, 40-inch-objective white telescope. The massive refractor's oversized pier pokes monolithically through the center of a 100-foot-wide floor that moves up and down like an elevator. A hole cut in the center of the floor allows this to happen. It's a sensation that, well, floors Hyakutake.

With all the mechanical groans you'd come to expect from a technological centurion, the massive refractor limbers to life. A fading twilight lingering in the west swings into view as the dome throws in an auditory commentary of its own. There, nestled in the stars of Perseus, is a faint streak of light that all this fuss has been about. The observatory director slips in an eyepiece seemingly as wide as a porthole. Yuji Hyakutake smiles.

July 1995 through 31 January 1996

The endless mornings of panning in altitude and azimuth yields nothing for Hyakutake, as is usually the case for even the most stalwart of comet hunters. Finally he decides it's his equipment that needs juicing up. The answer: a pair of 6-inch binoculars. Now, in July 1995, he's loaded for bear.

Then, on Christmas Day 1995 he finds his first comet moving among the stars of Libra. Almost immediately, four cloudy weeks descend like a pall. Finally, on January 31, 1996, it becomes partly cloudy, clear enough for Hyakutake to set up his 25x125 binos for a quick look at his first comet. But there, hardly 20° from his first discovery is another comet. Hyakutake can't believe his luck.

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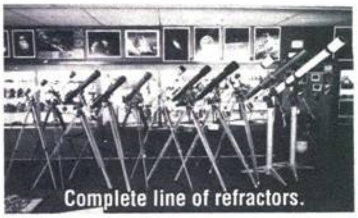

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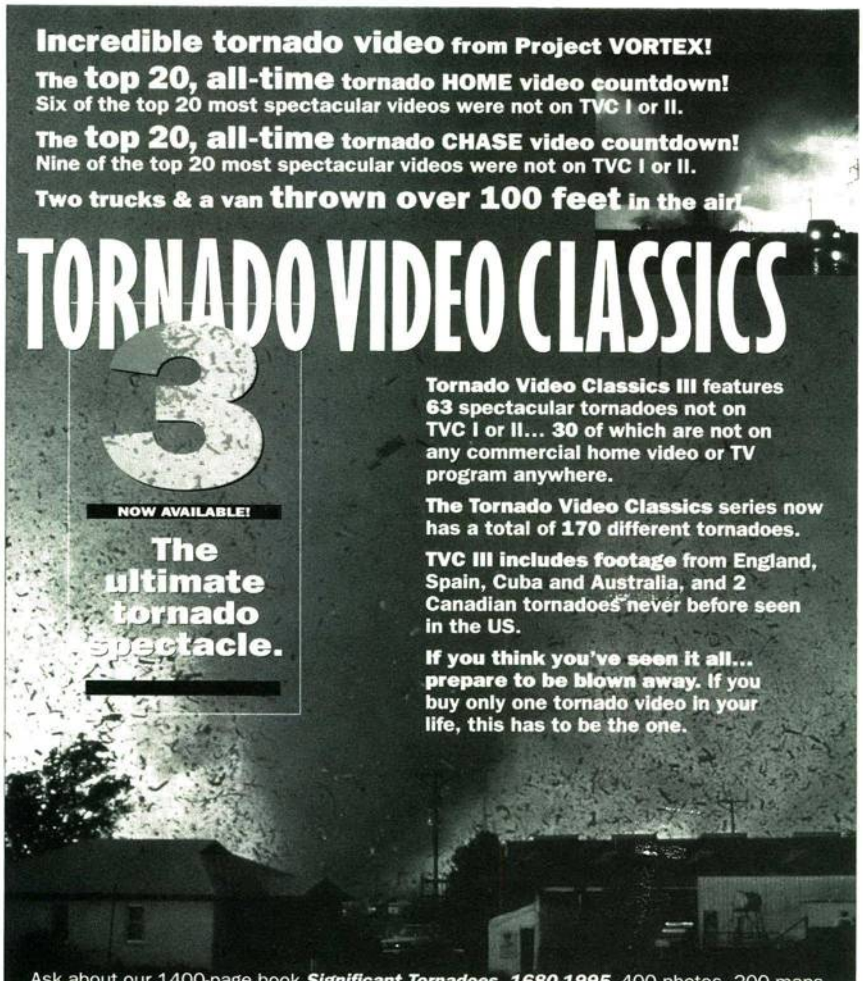

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Richard G. Kron/Yerkes Observatory

31 March 1996

Like the rest of the world, Hyakutake has been dazzled by his discovery of just two months ago. But the sooner things get back to normal the better. His wife laments about the media camping outside their home. The sooner this blows over, the sooner he can get out with his binos to look for comets. For now, though, with his heart racing at a thousand beats a minute, he queues up to the business-end of a 40-inch refractor. There in the field of view, through the same glass that conveyed the light of Comet Halley to E. E. Barnard's eager eyes in 1910, is *Hyakutake's* comet.

He and I lock eyes as he steps back from the scope. At that precise moment we're both 15-year-olds again, he basking in the light of his latter-day Ikeya-Seki, me soaking up the echo of 1976's Comet West under Upper Michigan skies.

Carried away by the spirit of the moment, I pull him aside and prop up a cast that covers my right leg's convalescing achilles tendon. I want his autograph. He chuckles and mentions through a translator that this is the first cast he's ever signed in his life. Is this an American tradition? Using a felt-tip pen, he scrawls out a greeting in the dome's subdued light: *31 March 1996, Yuji Hyakutake.* □

John Shibley is Associate Editor at ASTRONOMY *magazine.*

Brown Dwarfs Take Center Stage

Astronomers continue to gather information about brown dwarfs, objects heavier than planets but without enough mass to shine like stars. A spectrum recently taken of the most surefire brown-dwarf candidate has startled astronomers. The brown dwarf, which orbits the low-mass star Gliese 229, located 19 light-years away, has a complex near-infrared spectrum unlike that of any star or planet ever seen (see "Bingo!" AstroNews, March 1996).

The spectrum, the most detailed yet taken of this object, was obtained by a group led by Tom Geballe of the Joint Astronomy Centre in Hilo, Hawaii. Using the United Kingdom Infrared Telescope on Mauna Kea, Geballe's group found that the brown dwarf's atmosphere contains large quantities of water vapor, methane gas, and other molecules yet to be identified. Although astronomers thought brown dwarfs would closely resemble giant gaseous planets like Jupiter, the brown dwarf's spectrum more closely resembles that of Saturn's moon Titan than any other object in the solar system. Titan has a methane-rich atmosphere thicker than Earth's.

A group in Britain led by Hugh Jones of Liverpool John Moores University and Mike Hawkins of the Royal Observatory in Edinburgh, Scotland, has identified five brown-dwarf candidates within 130 light-years of Earth. Four of the objects are dimmer than one would expect stars to be at their distances. The fifth, named 296A, shows lithium in its spectrum. Stars quickly fuse lithium into heavier elements, so this object appears to be cooler, and therefore less massive, than a star.

Another Extrasolar Planet

Another planet orbiting a Sun-like star has been discovered by the planet-hunting team of Geoff Marcy (San Francisco State University) and Paul Butler (University of California at Berkeley). The planet has a minimum mass of 0.8 Jupiter and orbits the 6th-magnitude star Rho^1 Cancri. This star is located about 40 light-years from Earth, and is a G8 main-sequence star, meaning it is slightly dimmer and less massive than the Sun. The planet whizzes around Rho^1 Cnc in a mere 14.76 days and orbits the star at only 1/10 the Earth-Sun distance.

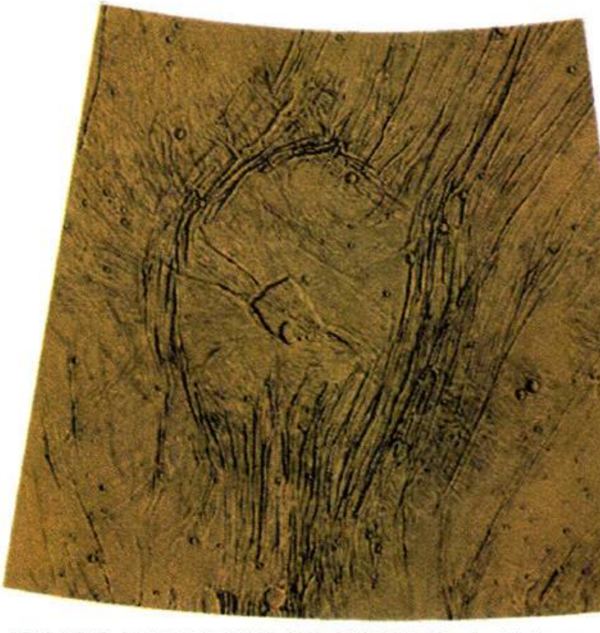
The planet's nearly perfectly circular orbit, mass, and orbital period very closely match those of the planet orbiting the star 51 Pegasi, suggesting the two planets formed in a similar manner (see "51 Pegasi Planet Update," AstroNews, May 1996). The planet's temperature is at least 700° C, making it much too hot to support life as we know it. The planet is too close to Rho^1 Cnc to be observed directly. Marcy and Butler discovered the planet by using the same method they employed to discover planets orbiting the stars 70 Virginis and 47 Ursae Majoris (see "Two New Solar Systems," April 1996): They detected the gravitational pull of the planet on its host star.

Does Mars Have Venus-like Coronae?

Alba Patera, a 700-kilometer-wide feature in Mars' Tharsis region, is a corona, says Ken Tanaka of the U.S. Geological Survey's Flagstaff field center. (Coronae are large circular structures discovered on Venus and are believed to be caused by rising "fingers" of magma that uplift and partially melt the surface rocks.) Tanaka and coworkers James Dohm and Thomas Watters of the National Air and Space Museum are now proposing that Mars has some 15 coronae, including Alba, which they point to as a best case.

"Many occur along fracture zones," says Tanaka. The team notes that Mars' and Venus' coronae both have similar diameter ranges (several tens of kilometers to hundreds of km), ring-like elevated rims cut by concentric faults and grabens, highly variable topographic and tectonic characteristics, volcanism, and locations along major fracture belts.

The researchers are now studying martian coronae in greater detail in hopes of modeling their formation history and working out the differences in tectonic style between Mars and Venus.



USGS

IS THIS A MARTIAN CORONA? If scientists are right, Mars' Alba Patera is a corona like those on Venus — and studying the differences may tell about the two planets' different volcanic and tectonic systems.

Fragment from the K/T Impact?

A core sample taken in the northern Pacific Ocean may contain the first identified chip off the asteroid whose impact put an end to the Cretaceous era 65 million years ago. Frank Kyte of UCLA reports that when he split open the core sample of brown clay, he found a 5-millimeter-long piece of light-brown, very fine-grained clay. Within that piece lay a 2.5-mm chip of broken rock.

The chip lay below a 10-centimeter layer of debris that dates to the time of impact. Kyte thinks the fragment may be ejecta that broke off the rear of the impactor (which hit the Yucatán peninsula) and was thrown as far as the Pacific by the fireball.

Studied in detail, the chip hints at an origin in a nickel-iron asteroid. It is rich in iridium and other elements commonly found in such asteroids but rare on Earth. Nearly all of its metallic nickel-iron has been destroyed by spending 65 million years on and in the ocean floor.

It's natural to wonder how likely it is that a random ocean core sample would pick up a piece of the impactor. It's actually not that bad, says Kyte. "If the figures for how much of a bolide can survive the impact are right, then we should find at least one more fragment in the same core."

He's looked, he says, but the search (which turned up nothing unusual) was only cursory. He plans a much more careful probe of the core, and to try to nail down the chip's association with the great impact.

Mead Crater Alters Venus Thinking

New studies of the Mead impact crater on Venus are forcing scientists to re-think their notions of the geologic history of our sister planet and to take a closer look at our own. So write Robert Herrick and Virgil Sharpton of the Lunar and Planetary Institute in Houston in the January 1996 issue of *Geology*.

Some researchers have come to believe that Venus is geologically quiescent. They base their conclusion on radar images from the Magellan orbiter, which apparently show that hundreds of craters on the planet are not surrounded, or "embayed," by lava flows. The new study, however, reveals that Mead is embayed, implying that other craters might be as well. Thus Venus may be more volcanically active than scientists had thought.

Herrick and Sharpton also point out that Mead is similar in size to Chicxulub, the crater in the Yucatán that is considered the mark of an asteroid impact that may have caused a mass extinction on Earth 65 million years ago. So scientists may be able to use Mead's surface appearance to help interpret Chicxulub, which is buried under nearly a kilometer of water and sediments. At the same time, the information gleaned from drillholes bored at Chicxulub could help researchers develop realistic models of how Mead formed. — *Alexandra Witze*

Jet Propulsion Laboratory

MEAD IMPACT CRATER on Venus, shown here in a Magellan image mosaic, may give Earth-bound scientists a way to study the buried Chicxulub crater in the Yucatán.

A One-Man X-ray Band

The Compton Gamma-Ray Observatory has discovered one of the most bizarre astronomical objects ever found, a hyperenergetic X-ray source with a split personality. The object emits episodic X-ray pulses twice a second. But when it was first discovered in the direction of the galactic center on December 2, 1995, it was also emitting as many as 18 X-ray bursts every hour in an erratic, spasmodic fashion. These bursts unleashed the energy of 1 million Suns from an area about the size of a small town.

Astronomers have discovered numerous X-ray sources that emit regular pulses, called X-ray pulsars, and a handful that emit erratic bursts, called X-ray bursters. But never before have astronomers observed an object that exhibits both behaviors. "We've seen some sources that play the drums, some that crash cymbals, and a few that play the trumpet. But this source is a one-man band," says astrophysicist Fred Lamb of the University of Illinois.

Astronomers think this object is another X-ray pulsar, consisting of a pulsar and a normal star in a 12-day orbit. The episodic pulses come from gas being siphoned off the normal star and channeled onto the pulsar's magnetic poles. The pulsar's gravity heats the gas to a billion degrees, causing it to erupt like a hydrogen bomb.

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Photo by Tony Hallas, taken with the 94mm f/7 BRANDON.

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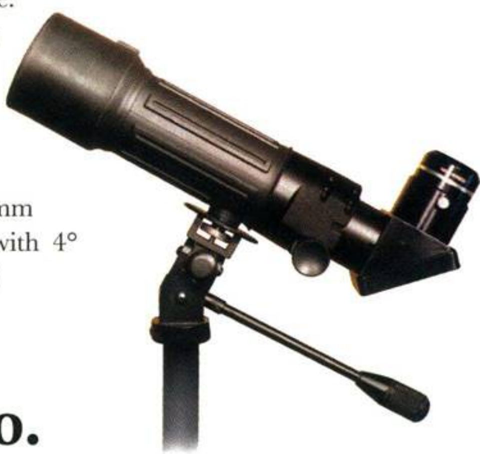

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Because the pulsar spins like a lighthouse beacon, one of these hot spots points toward Earth twice a second.

But X-ray pulsars aren't supposed to burst so erratically. Most astronomers think this odd behavior has something to do with an uneven flow of gas onto the pulsar. "There's a constant flow that creates the persistent emission, and occasionally you have blobs of matter falling onto the pulsar that causes the spasmodic activity. That is caused by an instability, but we don't know why or how," says co-discoverer Chryssa Kouveliotou of NASA's Marshall Space Flight Center.

Shape Up, Mars!

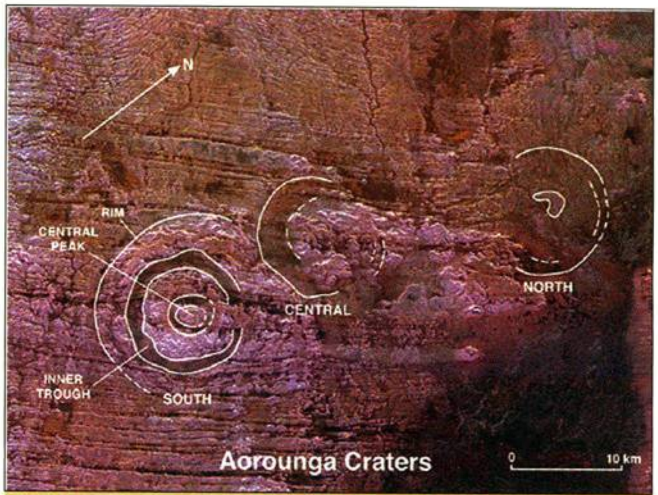
The vast northern plains of Mars may not lie 1 to 3 kilometers below the rest of the planet as scientists have long thought, say planetary researchers David Smith and Maria Zuber. The scientists, at NASA's Goddard Space Flight Center, base their conclusion on a careful analysis of orbital data from the Mariner 9 and Viking missions.

For years, planetary scientists have struggled to explain the relatively sharp change in elevation from the topographically high southern hemisphere to the low northern one. The boundary appears sharp, being about 700 km wide in most studies.

Smith and Zuber, however, say the elevation drop-off is a lot more gradual than it looks, with the surface sloping over thousands of kilometers. They claim the change in surface arises because Mars' center of mass and its center of shape do not coincide by an amount equal to about 3 kilometers, and this offset smoothes the gravity field across the boundary. Instead of a sharp topographic step, they say, material carried across the boundary (by erosion) would experience only a gentle slope.

They discovered the offset by exhaustively analyzing the ground tracking data from Mariner 9 and Viking Orbiters 1 and 2 in the 1970s. By applying sophisticated computer processing, Smith and Zuber were able to extract a new model for the gravity and shape of Mars that explains minute discrepancies in the motions of the spacecraft.

Now, it's back to the theorists to include the new model into accounts of the planet's geological evolution.



JPL/NASA

CRATER CHAIN IN AFRICA?

Three craters in northern Chad may come from a string of impacts, à la Comet Shoemaker-Levy 9. Two new craters were found east of a known impact crater named Aorounga (at left in photo), and are only the second chain of large craters known on Earth, according to Adriana Ocampo of the Jet Propulsion Laboratory. "These craters are highly eroded and buried by sand," says Kevin Pope of Geo Eco Arc Research, another member of the research team. "They are hard to see even if you're standing on the ground." (The image was taken in 1994 from the Shuttle Endeavour using the shuttle imaging radar system.)

The craters still need to be confirmed by fieldwork. "They could all well be impact structures," cautions geologist John McHone of Arizona State University, one of the team members. "But we don't have evidence to classify the new ones yet."

Where's the Clay?

Mars, it seems, is not the place to take up pottery. New work indicates that the Red Planet contains only a fraction of the clay that Earth does. The lack of clay minerals, which are a by-product of weathering on Earth, suggests that Mars and Earth may have had very different geologic pasts.

Roger Clark and Brad Dalton of the U.S. Geological Survey in Denver, Colorado, recently used data from the airborne AVIRIS spectrometer to study large areas of the western United States. They looked at spectra from more than 1,100 square kilometers in California, Nevada, and Utah — an area that, because of its aridity, should be a good analog to the surface of Mars.

That spectral image showed that the western soil contains a significant fraction of clay minerals. But when the researchers compared the Earth image to spectral images of Mars, they were stunned by the difference: Mars appears to have no more than 2 percent of the amounts of clay found on Earth.

Clark says nobody knows why there is so little Martian clay or what might be there in its stead. But the results suggest that the surface processes that shaped the surface of Mars may be very different than those on our home planet.

"On Earth, it's really hard not to form clays" through the normal course of weathering, says Clark. The fact that so little clay exists on Mars, he says, implies that "there must be a fundamental difference between the geologic history of Mars and that of *the Earth.*"

Clark adds that the lack of Martian clay may have

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rendered the planet even more inhospitable to life. Clay molecules provide a surface to which large molecules, including the building blocks of life, can stick. If there is little clay on Mars, the chance for life ever having existed there goes down dramatically.
— Alexandra Witze

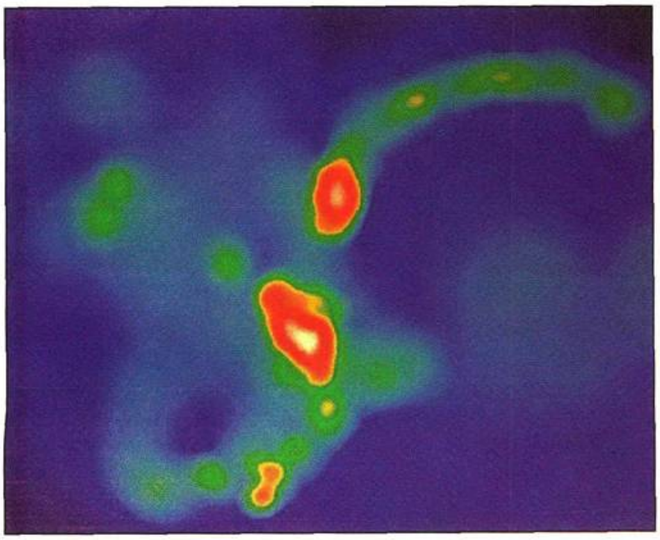
Why Most Stars Aren't Single

Unlike most stars in the Milky Way, the Sun has no stellar companion. About 60 percent of all the Galaxy's stars exist in binary systems.

With the help of a Cray supercomputer, astronomers from the University of Cardiff in Wales may finally have found out why nature prefers to make binaries. Their models of the chaotic process of star formation (see "Star-Maker," this issue) demonstrate three different processes that give rise to binary star systems.

In all three, stars form from collapsing knots of gas in giant gas clouds. The process begins when two cloud fragments collide, creating a layer of dense, compressed gas. The layer becomes gravitationally unstable and fragments into two or more filaments. Disks condense out of the knots in the filaments, and stars form inside each disk. But because the two initial cloud fragments usually don't collide head-on, the resulting filaments tumble end over end.

Sometimes two disks form in the same filament, creating a binary. Other times the filament, because it is tumbling end over end, causes the disk inside to spin faster until it breaks apart, forming two protostellar disks roughly the same size. In other cases, the spin rate is too slow. But because the filament is attracting nearby gas, spiral arms form. Eventually these arms become so massive that they break off and form protostellar disks.



Anthony Whitworth/Univ. of Cardiff

SPIRAL ARMS aren't just found in galaxies, as this supercomputer simulation of binary star formation shows.

EVENT HORIZON

Hydra in Water

The Infrared Space Observatory (ISO) has detected water vapor in the constellation Hydra the Water Snake. The discovery, which has nothing whatsoever to do with the fact that the constellation depicts a mythical, aqueous creature, was made using the long wavelength spectrometer aboard the ISO. Twenty water vapor emission lines were detected in the far-infrared spectrum of W Hydrae, a cool red-giant star. The discovery is expected to help astronomers understand how water molecules are formed and excited in gas flowing outward from stars.

Send Your Name into Space

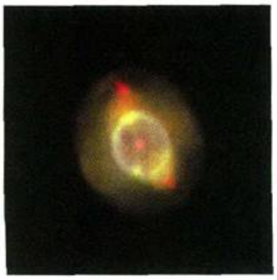
Volunteer members of the Planetary Society in Pasadena, California, are planning to send the digitized signatures of hundreds of thousands of people into space aboard the Cassini spacecraft bound for Saturn in 1997. The data will be loaded onto a CD-ROM or other digital media, and then mounted onto the Cassini spacecraft during its final assembly at NASA's Kennedy Space Center. To participate, signatures should be sent on a plain postcard to: Suzanne Barber, MS 264-441, Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109.

Shooting Stars on Mars

If you were standing on the surface of Mars at night, you would see shooting stars just like on Earth. A team of astronomers working in Britain and the United States has shown that even though Mars' atmosphere is much thinner than Earth's, it is still dense enough at high altitudes to cause incoming dust particles to burn up. Measurements of their location in the night sky would help astronomers understand the sources of dust distribution in the solar system. With a number of Mars missions due to take place in the next few years, martian meteor watching with automatic cameras could be a real possibility.

Planetary Nebulae and Planetary Systems

A study published in the March 20, 1996, *Astrophysical Journal Letters* asserts that brown dwarfs and gas-giant planets may endow some common planetary nebulae with their elliptical structure. According to the study, elliptical planetaries are a result of tidal interactions between the central star and at least two stellar or substellar companions. Statistical analysis indicates that brown dwarfs or gas-giant planets may be prevalent around main-sequence stars.



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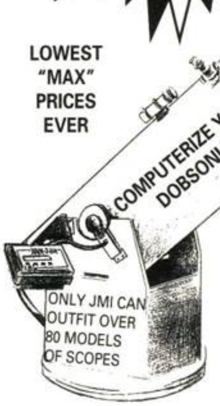
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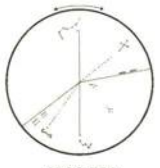

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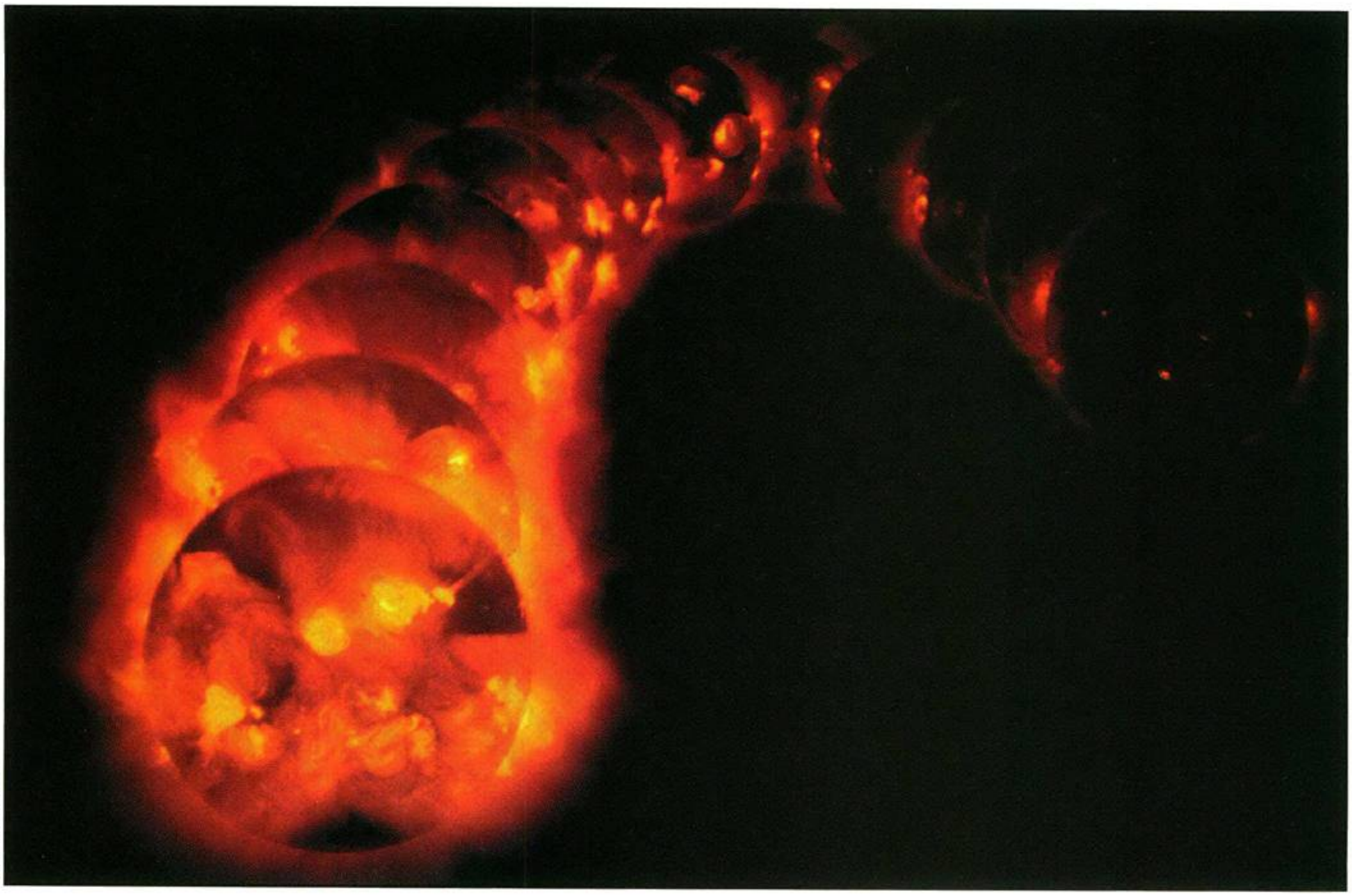
Lockheed Martin

THE SUN'S CORONA CHANGES DRAMATICALLY during the waning phase of its 11-year activity cycle. These 12 images, taken with the Soft X-ray Telescope on the Earth-orbiting Yohkoh satellite, show the 2-million-degree corona fading by a factor of one hundred during the cycle. The images were taken at approximately four-month intervals beginning on November 12, 1991, during the most recent peak of activity (left), and running until July 27, 1995, shortly before solar minimum (right). The coronal structure, which is controlled by the Sun's magnetic field, transforms from a complex, highly structured state at solar maximum to a simpler configuration featuring far fewer magnetic field lines at solar minimum.

Where Cosmic Rays Come From

Scientists from the United States and Japan appear to have solved a long-standing mystery: the origin of cosmic rays. Cosmic rays are not really rays at all, they are super-energetic subatomic particles that streak through space at near-light speeds. Earth's magnetic field protects us from most cosmic rays, but some of them interact with the upper atmosphere, creating a shower of secondary particles that reach the surface.

But where do cosmic rays come from, and how are they accelerated to such high speeds? They bombard Earth from all directions, so astronomers can't pinpoint their location in space. Astronomers surmised that only shock waves produced by supernova explosions could do the trick.

In the November 16, 1995, *Nature*, the international team provides strong evidence that astronomers had been right all along. Data from the Japanese-American X-ray satellite ASCA show that cosmic rays are produced in high quantities in the remnant from the brightest historic supernova, which appeared as bright as the quarter Moon in 1006 A.D.

Two regions on opposite sides of the remnant glow intensely in synchrotron radiation, which is produced by electrons moving at near-light speeds in a magnetic field. From the strength of this emission, the team concludes that cosmic rays are accelerated in these regions. Subatomic particles bounce back and forth between turbulent areas of the remnant, constantly gaining energy until they attain ultra-high speeds. "Since we found cosmic ray acceleration underway in the remnant of Supernova 1006, this process probably occurs in other young supernova remnants," says team member Robert Petre of NASA's Goddard Space Flight Center. □

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Firstscope 80 EQ – The **best buy** in refracting telescopes – high performance and unbeatable price.

The **Firstscope 80 EQ** telescope is a good choice for the more serious beginning astronomer. An 80mm (3.1") aperture. The objective is an air-spaced achromat designed to yield the finest images available in this class of instrument. It has a 910mm focal length (f/11.4).

The equatorial mount is stable and includes setting circles in both axes as well as slow-motion cables in both axes for easy tracking. The wood tripod is adjustable in height and includes an accessory tray.

For astronomy you can enjoy breathtaking views of the Moon, Saturn with its ring structure, Jupiter and its belts and hundreds of deep-sky objects including galaxies, nebulae and star clusters. With a solar filter (optional) you can observe activity on the Sun. For terrestrial use, enjoy vistas from view homes or take your instrument out in the field to take advantage of our natural environment up close.

Standard accessories include a 6x30 Finderscope, 1¼" Focuser, 25mm SMA Eyepiece – 1¼" (36x), Star Diagonal – 1¼". Weight is 24 lbs.

4" REFRACTORS

Celestron offers two models of 102mm (4") equatorial refractor telescopes. These telescopes are for the more serious astronomer who appreciates superb optics and ultra-stable mounts.

The Great Polaris (GP) German equatorial mount is standard. Both axes have precision 144-tooth lapped worm gears for very smooth motion. The adjustable height, very rigid wood tripod has excellent vibration dampening characteristics and has a handy accessory tray.

The GP mount has a built-in illuminated polar alignment scope for fast polar alignment.

The premium optics of the **GP-C102** are made in Japan to rigid standards. It has a focal length of 1000mm (f/9.8). The **GP-C102-ED** model features Super ED glass to yield exquisite images of very high contrast and resolution with virtually no chromatic aberration. The ED unit has a focal length of 920mm (f/9) and has multi-coatings.

Standard accessories (the same on both models), include a 20mm Eyepiece – 1¼", 6x30 Finderscope with an 8° field and a Star Diagonal – 1¼". Weight is 39 lbs.

Optical tube assemblies of the 4" refractors are available separately and include tube rings, mounting plate and finderscope.

CELESTRON REFRACTING TELESCOPES:

The 60mm (2.4") refractor is the most popular telescope size for the beginning astronomy enthusiast or for casual gift-giving. It can introduce newcomers to the exciting hobby of astronomy at an affordable price.

FIRSTSCOPE 60

A 700mm focal length (f/11.7) telescope which contains all glass optical components with coated optics.

The glossy black telescope optical tube is made of aluminum. The sturdy altazimuth mount has a slow-motion control rod for vertical adjustments. The rigid, adjustable wood tripod includes an accessory tray.

Standard accessories include a 20mm H – .96" Eyepiece (35x), 6mm SR – .96" Eyepiece (117x), 2x Barlow Lens – .96", 5x24 Finderscope and a 90° Diagonal.

FIRSTSCOPE 60 DELUXE

The same as the Firstscope 60 except that all the .96" items are replaced with a **hybrid 1¼" diagonal and two 1¼" eyepieces** – 25 SMA (28x) and 10mm SMA (70x).

Celestron offers two 60mm equatorial refractors – the Firstscope 60 EQ and the Firstscope 60 EQ Deluxe.

FIRSTSCOPE 60 EQ

Similar to the Firstscope 60 but the focal length for this telescope is 900mm (f/15).

Standard accessories include a 20mm H – .96" Eyepiece (45x), 12.5mm H – .96" Eyepiece (72x), 2x Barlow Lens – .96", 6x24 Finderscope and a 90° Diagonal. Weight is 11 lbs.

FIRSTSCOPE 60 EQ DELUXE

The same as the Firstscope 60 EQ except that all the .96" items are replaced with a **hybrid 1¼" diagonal and two 1¼" eyepieces** – 25mm SMA (36x) and 10mm SMA (90x).

The 1¼" accessories give you sharper images, a wider field of view and better eye relief. Weight is 11 lbs.

Celestron offers a premium grade 80mm (3.1") altazimuth refractor – **The Premium 80.** The premium built optics are made in Japan.

The Premium 80 is an ideal first telescope for the more serious beginning astronomer or terrestrial observer.

Its easy-to-use altazimuth mount includes slow-motion controls in both axes with flex cables allowing quick and easy pointing and tracking. The supplied attractive and very sturdy wood tripod is adjustable in height.

Standard accessories include a 26mm multi-coated Plössl – 1¼" Eyepiece (35x) for a wide field of 1.4°, high quality 6x30 Finderscope and a versatile 45° Erect Image Diagonal – 1¼". Weight is 18 lbs.

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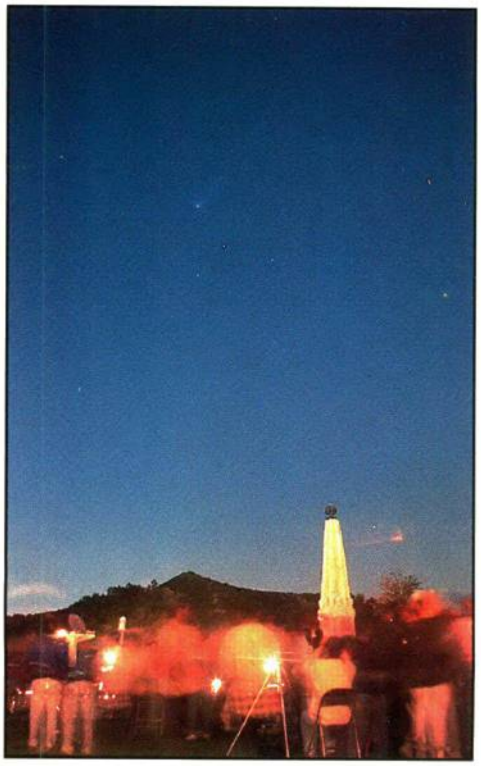
Hyakutake Outshines the Oscars

While the close approach of comet Hyakutake in March hit the media everywhere, planetariums around the country scrambled to provide information, lectures, and observing sessions for the public.

Staff astronomers at Hayden Planetarium in New York City joined forces with the Amateur Astronomers Association of New York and the New York City Urban Park Rangers for a comet fest in Manhattan's Central Park.


John Hodge

HYAKUTAKE ATTRACTED a stellar turnout at Griffith Observatory on Mount Hollywood.

Additionally, displayed inside the planetarium was a 6' by 4' model of an outgassing comet built by staff member Brian Sullivan.

In the Midwest, Adler Planetarium in Chicago not only welcomed comet discoverer Yuji Hyakutake to the "windy city," but also provided two weeks of public observing sessions to approximately 500 people nightly. Adler's creative staff also produced a poster of the comet for distribution and sale, which Hyakutake signed during a program on Friday, March 29.

Three nights of public observing gave almost 4,000 people a mile-high comet experience in the Colorado Rockies. Working with the Denver Astronomical Society, Gates Planetarium of Denver offered several unique demonstrations, including a remote connection to Software Bisque's Blue Mountain Observatory in Golden, Colorado. CCD images were taken at the planetarium through an ST-6 CCD camera attached to a 20-inch telescope in Golden, a distance of about 40 miles.

In the western United States, comet mania attracted over 25,000 people to the Griffith Observatory in Los Angeles, California. In spite of the star-studded Academy Awards on March 25, Griffith had a stellar turnout for Hyakutake. Comet observing was plentiful on the southern slopes of Mount Hollywood.

Next to another ocean under clear skies, "star hustler" Jack F. Horkheimer and his staff provided 10 days of lectures and telescopic viewing for the several thousand people visiting the Miami Space Transit Planetarium. Experts there formed a comet team and presented taped and live lectures.

In the two months from Hyakutake's discovery to closest approach, plenty of work had to be done. Amateurs and professionals alike pooled resources and ideas to provide the public with information and opportunities for observing the brightest comet in 20 years.

This practice should prove useful as everyone gears up for Comet Hale-Bopp in 1997.

The Late, Great Planet Sallit

If a stray blip shows up on one of your astrophotos, be very careful who you show it to. British astrophotographer George Sallit found this out the hard way last winter after a stray asteroid appeared on one of his pictures. Its minuscule streak showed up in a CCD image he took of the galaxy NGC 772 in Aries. By the time he noticed the interloper several weeks later, too much time had lapsed to take another photo and calculate an orbit. The stray observation was sent to Harvard's Minor Planet Center, where it was added to dozens of other "one night stands" turned in each year.

But the experience opened Sallit's eyes to what urban backyard astronomers could accomplish with a CCD camera on the right scope. In that spirit, he appeared on a radio talk show to encourage other amateurs. This piqued the interest of a local paper, which ran his asteroid discovery story. That's when the problems began.

"The story was given to a regional press agency and they decided to make it more interesting," says Sallit. "They changed 'a few million miles away' to '400 million miles' and 'less than a few tens of miles across' to '40 miles.'" Reporters coined a new planet: Sallit One. Soon the national and world media were beating a path to the discoverer's door.

Now, several months later, Sallit is finally at peace with the Press. One tangible result does remain from the whole episode, however. "The local police advised me to fit a burglar alarm onto my observatory," he laments. "Is my observatory the only amateur one in the world with a burglar alarm?"

And what of Sallit One? The nameless, tiny chunk of rock silently moves in an unknown orbit around the Sun, waiting to bestow fifteen minutes of fame upon its next victim.

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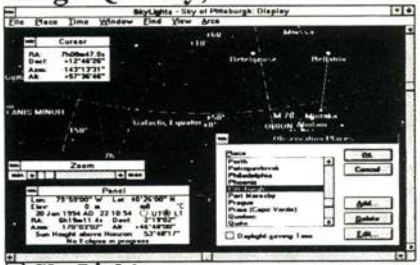
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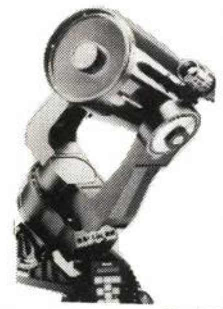

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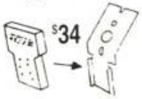

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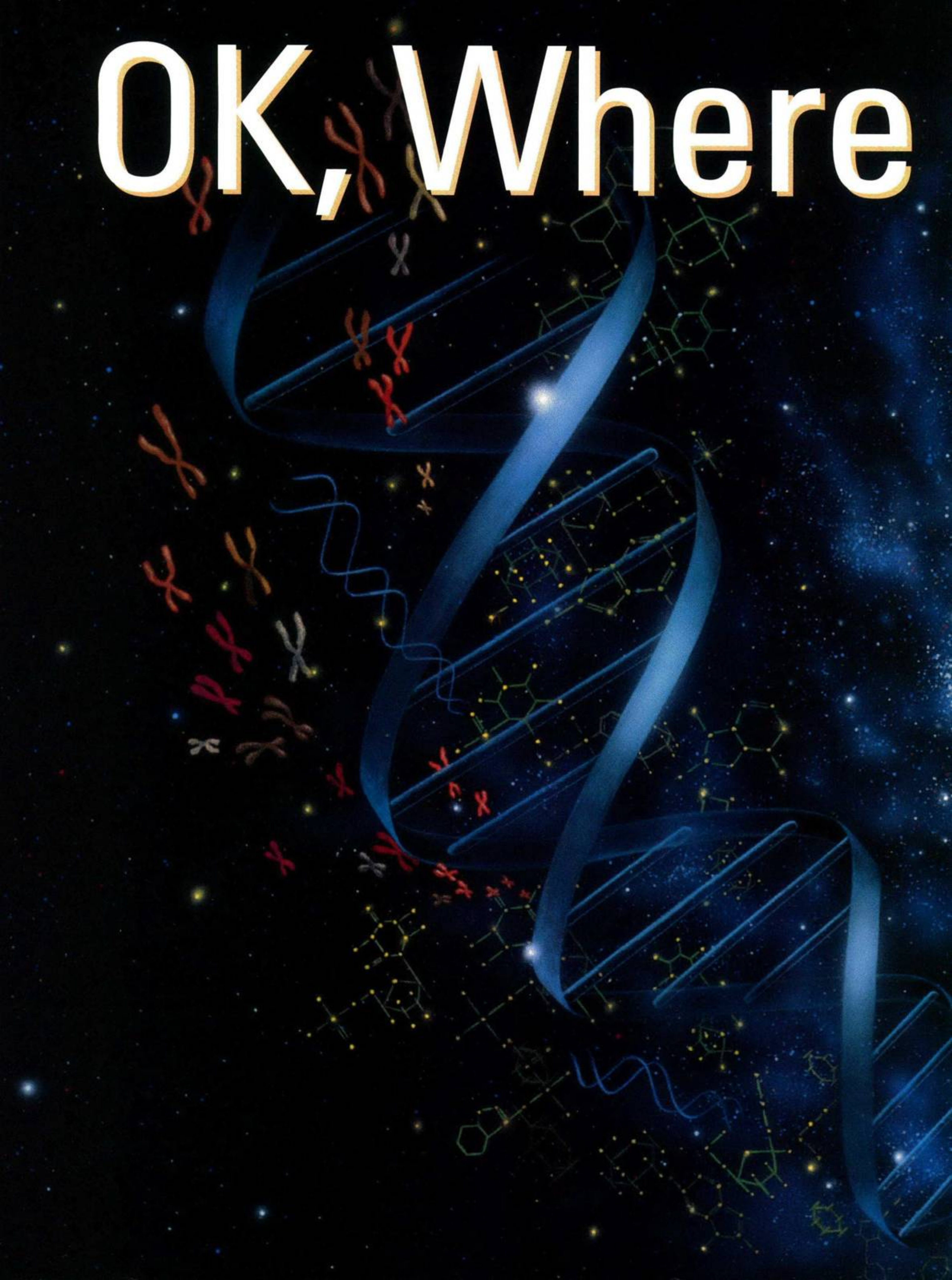

Are They?

Evidence from a variety of scientific fields indicates that we might be the lonely inhabitants of a vast cosmic ocean.

BY ROBERT NAEYE

Lynette Cook

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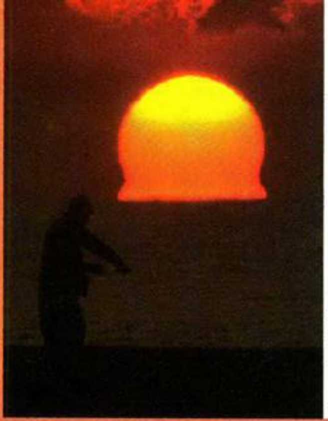

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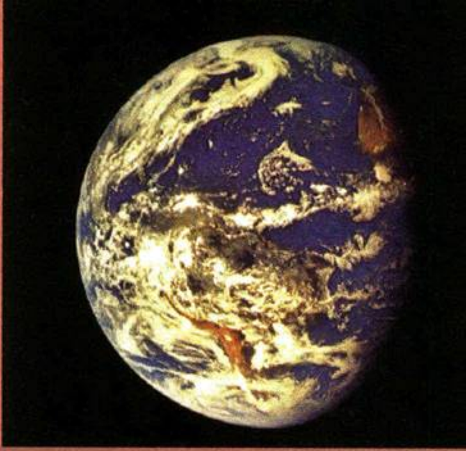
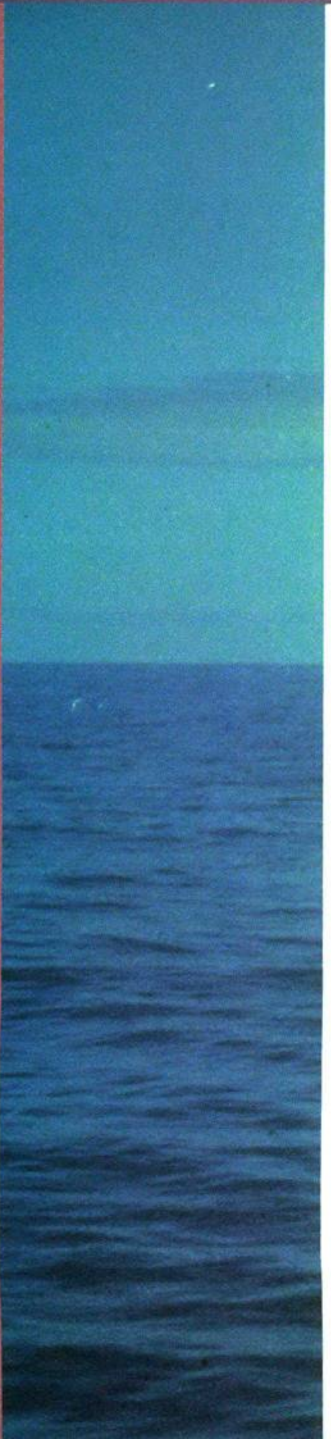




NASA

Humans thrive nearly everywhere on Earth. From the sweltering Amazon rain forest to the bone-dry Sahara Desert, and from the frigid Arctic wastelands to isolated Pacific islands, people have adapted to hostile conditions.

Is the Milky Way Galaxy like planet Earth, with towns and cities dotting the landscape? Or is Earth more like a lonely island in a vast galactic ocean, with life-bearing planets and especially intelligent life separated by vast distances?

On the surface, the most obvious evidence bearing on these questions is the fact that our home world and host star seem so ordinary. Nicolas Copernicus shattered the prevailing notion that Earth was seated at the center of creation. Succeeding generations of astronomers steadily reinforced the Copernican view as they discovered the true nature of stars, the remote location of our home world within our Galaxy, and the existence of galaxies far, far beyond our own. So pervasive is this view that in the world of modern science, it is almost considered heresy to assert any special qualities to our solar system, our planet, or even ourselves. With an estimated 200 billion stars in the Galaxy and interstellar space filled with the molecules necessary for life, many scientists and laymen naturally conclude that we could not be alone — we must share our Galaxy with hundreds, thousands, or perhaps millions of other civilizations.

But on closer examination, this simple logic falls apart. Recent studies in a variety of scientific fields suggest that life must pass through a series of bottlenecks on the road to intelligence. On Earth, a long sequence of improbable events transpired in just the right way to bring forth our existence, as if we had won a million-dollar lottery a million times in a row. Contrary to the prevailing belief, maybe we are special. Maybe humanity stands alone on a fertile island in the largely sterile waters of the galactic ocean.

ALL EARTH LIFE is based on liquid water. The same will probably be true on other worlds.

Scientists who ponder this deep question are limited by the fact they have only one example of life to study: life on Earth. Science-fiction writers have envisioned an amazing variety of life-forms totally unlike any on our planet. But sci-fi writers are limited only by their imaginations, not by physical reality. Life as we know it, from astronomy aficionados to the lowest bacteria, shares several fundamental characteristics, and most scientists think these will be common to all life in the universe.

First, life takes in matter and energy from its surroundings, uses it for food, reproduction, and locomotion, and expels waste. Second, life stores information and replicates it in future generations (that's a fancy way of saying "sex").

The liquid state is ideal for these tasks. Liquids can dissolve both solids and gases, producing complex molecules. And those molecules can move about freely and come into contact with other molecules, hastening chemical reactions. In gases, atoms lie too

A SPECIAL PLANET with all the right conditions is necessary to support life.

NASA

A SECURITY BLANKET of air is needed to moderate surface temperatures and provide sustenance for life.

NASA

far apart to allow the formation of complex molecules capable of storing information. And in solids, molecules are locked in place, so chemical reactions necessary to transfer information from generation to generation proceed much more slowly than in liquids. On Earth, where all life is based on the liquid state, 3.8 billion years elapsed between the first microbes and fast food restaurants. If life on another planet were based on solids, the time needed for intelligent life to evolve would be longer than the age of the universe.

Intelligent life not only needs to be based on a liquid, it probably needs to be based on liquid water. On Earth, water is literally the molecule of life, comprising 70 percent of a cell's mass. There are good reasons to think this will be true elsewhere. Water is the most abundant molecule in the universe likely to be found in a liquid state and it has a wonderful ability to dissolve inorganic chemicals so living organisms can use them. Other liquids, such as ammonia, don't share water's versatility. It's no coincidence that the only body in the solar system with liquid water on its surface — Earth — is the only known life-bearing world.

Some life-forms in the universe might be based on other liquids, but most biologists think the ones most likely to evolve high intelligence will be based on water. This establishes a rather stringent requirement for intelligent life: It needs a stable temperature for billions of years so water can remain in a liquid state.

To evolve intelligence, life needs a star that can serve as an incubator for a life-bearing planet by providing relatively stable temperatures for billions of years. But only a small fraction of the Milky Way Galaxy's 200 billion stars fit the bill.

One that fits it perfectly is the Sun. This middle-aged star has a slightly above-average size and mass, and it produces a steady energy output. But the Sun, unlike the majority of stars, has no stellar companion. Roughly two-thirds of Milky Way stars belong to binary or multiple star systems. In most multiple star systems, either planets won't form, or varying gravitational forces will yank planets into tortured, elongated orbits. At one point in its orbit a planet will come very close to a star's searing heat, causing liquid water to evaporate. At other times it will venture far, far away, and water will freeze as temperatures plunge to a few degrees above absolute zero. Intelligent life could never evolve on such planets.

Most single stars cannot support life either. Some 80 percent of all stars — those with less than 65 percent of the Sun's mass — are just too wimpy to support life because they radiate so little energy. A planet close enough to receive enough heat to keep water in a liquid state will orbit so close that tidal forces from the star will slow the planet's rotation to a crawl, as happens between Mercury and the Sun. One hemisphere faces the star for extended periods of time, becoming too hot, and the other faces away, becoming too cold. Many of these dwarf stars also spew huge flares into space that periodically toast any nearby planets.

On the other end of the scale, stars 40 percent more massive than the Sun or larger don't live long enough to produce technological civilizations. These celestial behemoths, which make up about one percent of the Galaxy's total, consume their hydrogen fuel like hungry sharks at a feeding frenzy. On the cosmic time scale, they live out their lives in a blink of an eye.

The Sun belongs to a precious minority of stars that have no stellar companions and that have the right mass. Nobody knows exactly how many stars can support intelligent life, but it's clear these criteria have put a dent in the most optimistic ET claims by whittling 200 billion stars down to perhaps 10 to 20 billion.

Ten or 20 billion good suns is still a lot of good suns. But how many have planets that can support life? The discovery of planets orbiting the Sun-like stars 51 Pegasi, 70 Virginis, and 47 Ursae Majoris has fueled the optimism of extraterrestrial life proponents. But on closer inspection, the new planets paint a less rosy picture.

The planet orbiting 51 Pegasi is a Jupiter-mass world orbiting so close to its star that it's baked to a searing 1000 degrees (see "Is This Planet for Real?" March 1996). Most astronomers think the planet formed much farther from its star and then migrated inward due to tidal interactions with the disk from which the planet formed, stopping just short of a fiery

A MAGNETIC FIELD creates the aurora, but also protects a planet's surface from deadly radiation.

Bill Tetley

death. But if the system once contained terrestrial planets, they weren't so lucky. Astronomers think terrestrial planets will spiral into their parent star — and their doom — if the protoplanetary disk is long-lived.

The 70 Virginis planet has been touted as a good life-bearing candidate because it lies in a zone where water can exist in liquid form (see "Two New Solar Systems," April 1996). But the planet has a highly elliptical orbit, subjecting the world (and any moons that might be orbiting it) to wild climate variations. Moreover, the planet is so massive (at least 6.5 times that of Jupiter) that its elliptical orbit would completely eject any inner planets from the system.

Of all the new planetary systems discovered to date, the 47 Ursae Majoris system is the closest analog to our own. But even that system offers little prospect for life. Most astronomers think Jupiter's immense gravity prevented a planet from forming in the asteroid belt. The 47 Ursae Majoris planet, being at least 2.3 times more massive than Jupiter and closer to its star, would play havoc with the planet-formation process within the star's life zone.

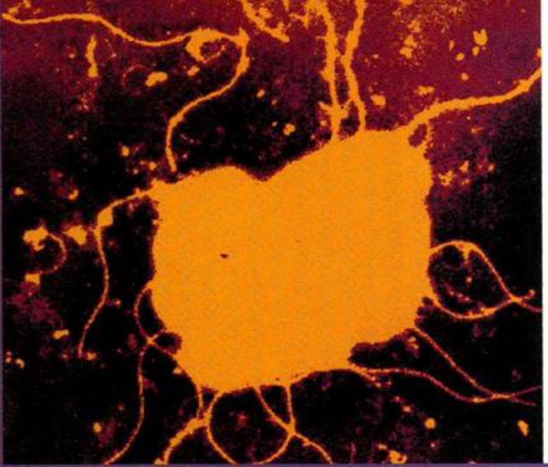
Astronomers have good reason to think that planetary systems like our own — with rocky inner planets and gas giants starting at about Jupiter's distance from the Sun — offer the best prospects for life. The rocky planets serve as the abodes for life, while the massive planets cleanse the systems of most of the junk left over from the planet-formation process. Recent computer simulations by George Wetherill of the Carnegie Institution in Washington, D.C., show that without Jupiters, killer asteroids and comets would constantly bombard any rocky inner planets. Instead of impact-induced mass extinctions (like the one that wiped out the dinosaurs) occurring every 100 million years, they would happen every 100,000 years. Life would never have the opportunity to evolve toward intelligence.

But astronomers have unsuccessfully searched several dozen nearby Sun-like stars for Jupiter-mass planets in Jupiter-like orbits, suggesting that gas giant planets might be relatively uncommon. Computer models indicate that a planet needs at least 10 million years to gobble up enough gas from a protoplanetary disk to attain the mass of Jupiter. Radio observations of nearby stars only a few million years old show that most are not surrounded by enough gas to form heavyweight planets like Jupiter. So for a solar system to be habitable, it needs to form from a disk that lives long enough to enable a Jupiter to reign in sufficient gas, but not so long that the terrestrial planets spiral all the way into the star. Our solar system might be one of the few where everything happened just right to give life a fighting chance.

Many astronomers bemoan the Moon as a worthless hunk of rock that washes out the night sky for about two weeks every month. But without the Moon, there might not be anyone on Earth capable of enjoying the wonders of the universe. Compared to the other terrestrial planets, the Earth-Moon system stands out. Mercury and Venus have no satellites at all, and Mars has two insignificant, Manhattan-sized boulders that are probably captured asteroids. Earth can brag about its massive Moon, however, which is about the same size as the largest satellites of Jupiter and Saturn. It's no wonder that many astronomers refer to the Earth-

VOLCANISM and shifting crustal plates regulate atmospheric gases and the climate.

NOAA



Peter Appelbaum

LIFE MUST ARISE before it can evolve toward intelligence. Was this a one-in-a-million event?

Moon system as a double planet.

Research by Jacques Laskar and colleagues at the Bureau des Longitudes in Paris shows that the Moon's considerable gravity acts as a stabilizing anchor on Earth. Without the Moon, subtle gravitational effects from the other planets (mainly Jupiter) over millions of years would play havoc with the tilt of Earth's spin axis. Instead of the current 23.5-degree tilt, which gives us our moderate seasonal variation and which varies by only 2.6 degrees over a 41,000-year period, the axial tilt would fluctuate chaotically between 0 and 85 degrees over millions of years. Earth's climate would experience eons of wild seasonal variation, followed by periods with none at all. Such unstable environmental conditions would probably lead to either a runaway greenhouse effect, which heats Venus' surface to a hellish 450 degrees Celsius, or runaway glaciation, which would plunge Earth into a permanent ice age.

Probably very few Earth-sized planets in the Galaxy have satellites as large as our friendly neighbor. Most astronomers think the Moon formed by a freak accident. Early in the solar system's history, a Mars-sized object crashed into Earth at just the right angle so as not to destroy Earth, but to blast a hefty chunk of material into space that later coalesced into the Moon. This might have been a one-in-a-million event, but one that appears necessary to have allowed intelligent life to evolve.

But perhaps the most fortuitous circumstance of all is the fact that water remained in a liquid state as the Earth and Sun went through major changes. When Earth formed 4.6 billion years ago, the Sun was 30 percent dimmer than it is now, according to stellar evolution models. At the time, Earth had a totally different atmosphere. It started off with an atmosphere consisting mostly of nitrogen, carbon dioxide, and carbon monoxide. Over billions of years, biological and geological activity removed most of the carbon from the atmosphere and replaced it with the free oxygen that now provides sustenance for all animal life.

Remarkably, as the Sun heated up, and Earth's atmosphere completely changed over in composition, Earth's average temperature remained confined within a narrow range conducive to life, always staying between 5 and 60 degrees Celsius. How has Earth managed to avoid either a runaway greenhouse effect or a permanent ice age?

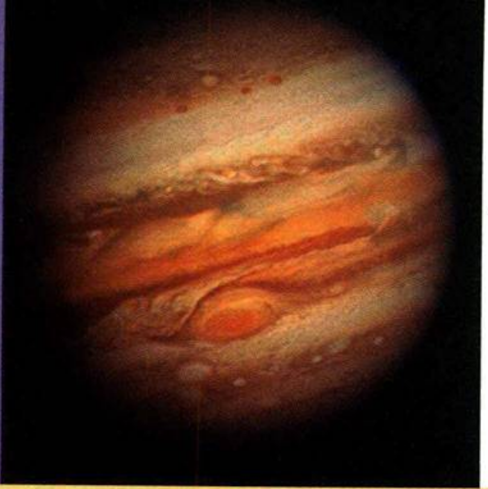
Geologists propose that a global thermostat ensures the atmosphere becomes neither too hot nor too cold. Volcanism and the motions of shifting oceanic and continental plates cycle carbon between the atmosphere and the interior. When Earth's climate cools, the process allows carbon dioxide levels in the atmosphere to rise. Since carbon dioxide is a greenhouse gas that traps heat, this warms the planet. When the Earth warms up, the mechanism removes carbon dioxide from the atmosphere, so the planet cools. This thermostat, many Earth scientists believe, has maintained a stable climate for eons.

How many planetary systems in the Galaxy orbit a good sun, have a Jupiter, and have a rocky planet with both a large moon and a perfectly working thermostat? No one can say for sure, but it's probably a very small number. The moral of the story is that good planets are hard to find.

Even if we assume that life originates on a good planet orbiting a good sun, it's by no means inevitable that a species with high intelligence will ever evolve. Many evolutionary biologists think the evolution of a highly intelligent species like *Homo sapiens* was a one-in-a-billion long shot.

In his book *Wonderful Life,* Harvard paleontologist Stephen Jay Gould corrects the common misconception that evolution is a "march of progress" toward increasingly advanced life and intelligence. Instead, as Gould explains, the evolution of life is like a tree. *Homo sapiens*, like all of Earth's modern-day species, is but one tiny twig at the end of a long chain of increasingly smaller branches. No single twig is more "advanced" than any other twig; evolution does not work toward a goal.

Gould's Harvard colleague Ernst Mayr argues that the evolution of a twig capable of high technology is exceedingly improbable. He notes that only one of the four major kingdoms of life, the animals, went on to produce intelligence. Only one of the 70 phyla of animals, the chordates, produced intelligence. Only one



NASA

OUR GUARDIAN ANGEL Jupiter deflects comets and asteroids that would otherwise smash into Earth, triggering mass extinctions.

OUR ROCK OF STABILITY, the Moon, keeps Earth's spin axis from flip-flopping chaotically.

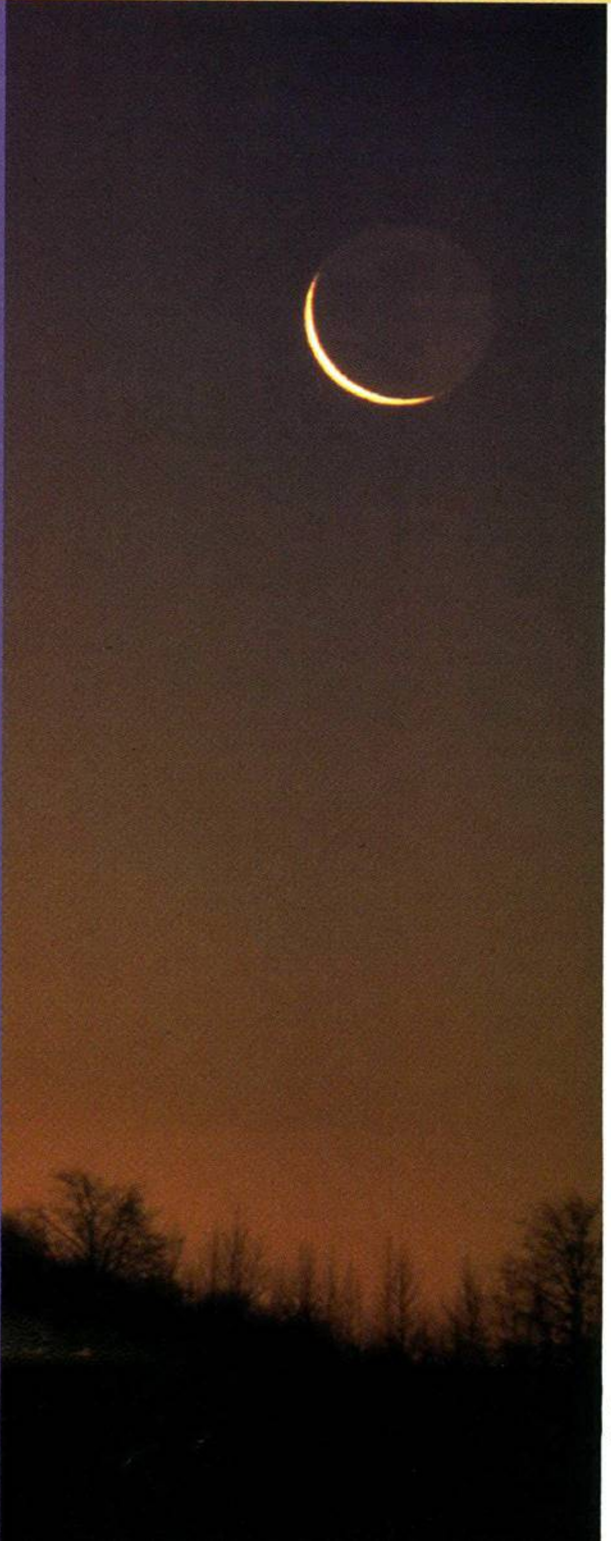
class of chordates, the mammals, produced intelligence. Only one order of mammals, the primates, and only one family of primates, the great apes, produced high intelligence. And only after 25 million years of evolution and many failed lineages, did one particular ape evolve that was capable of high technology.

Our own lineage went through through millions of species. Because evolution is primarily a game of chance, any seemingly minor past event could have gone slightly different, cutting off our evolutionary line before humans evolved. ET proponents should be deeply discouraged that none of the millions of other lineages, representing the billions of species that have inhabited Earth during its existence, have made substantial progress toward high intelligence.

Unlike the development of eyes, which have evolved independently at least 40 different times in Earth's history, there has been no evolutionary "convergence" toward high intelligence. Intelligence may have evolved several times, but only in humans was it combined with the manual dexterity needed to make tools. And that combination seems to be the key that allowed humans to develop their high technology.

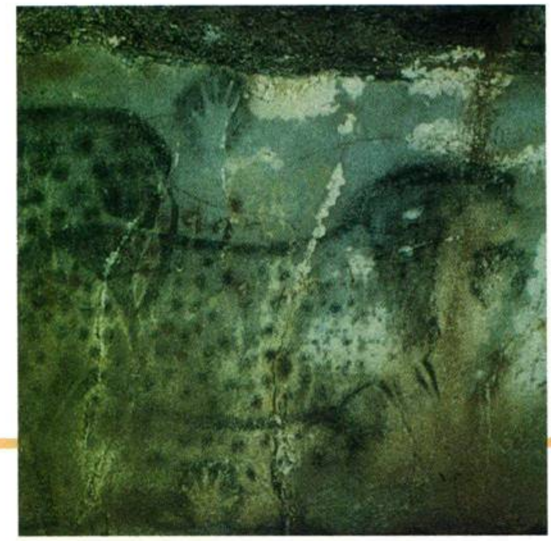
The long series of bottlenecks makes it clear that the emergence of intelligent life is far more difficult than scientists once thought. There are probably more obstacles that scientists haven't even stumbled across yet. The origin of life on Earth, for example, might have been the ultimate long shot. ET proponents might counter that this line of reasoning is based on mere anthropocentric speculation. Maybe life and even intelligent life can take on various forms that we can't even imagine.

But alternative life-forms are the epitome of speculation. If one chooses to shun speculation and stick solely with observations, one can ask the same question that Nobel physicist Enrico Fermi put forth in 1950: If the Galaxy is teeming with intelligent life, where are they? The sobering reality is that there is no observational evidence whatsoever for the existence of other intelligent beings anywhere in the universe. If intelligent life is commonplace, our current astronomical instruments could possibly see evidence of their activities. But as UCLA astronomer Ben Zuckerman



Alan Dyer

TO DEVELOP TECHNOLOGY, life needs to evolve high intelligence and manual dexterity, an unlikely combination.



Gallery of Prehistoric Art

NUCLEAR ARMAGEDDON, pollution, asteroid impacts, and other disasters can extinguish a civilization. What is our fate?

National Archives

points out, there is no hint that the hand of technology has touched the universe. He notes that the Infrared Astronomical Satellite could have detected heat radiation from large-scale space colonies or astroengineering projects around several hundred Sun-like stars.

Even recognizing the vast distances between the stars, it's hard to imagine that all technological civilizations will remain confined to their home planetary systems. Just 40 years into our Space Age we have four probes leaving the solar system. In the year 1900 anybody would have laughed at the proposition that such an event would take place before the end of the century. With scientific knowledge doubling every 20 years, it would be equally shortsighted to rule out interstellar travel. If the Galaxy is teeming with technological civilizations, some of them will overcome the problems of interstellar travel and venture into deep space. Some will launch automated probes to explore other star systems. Some will send emissaries to colonize other planets. Others will migrate when their sun's hydrogen-burning life-cycle ends.

When civilizations do venture into the Galaxy, our solar system, with its nurturing Sun and wealth of resources, will be a lucrative target. But UFOs, faces on Mars, and ancient astronauts notwithstanding, there's not a shred of credible evidence that Earth or even our solar system has ever been visited by extraterrestrials. Even if ETs have a "Prime Directive" prohibiting interference with life on Earth, they would be tempted to exploit the vast supply of iron, nickel, and other minerals in the planets and asteroids. But our solar system appears totally pristine, as if no outsiders have been here before.

This evidence is far from definitive. Extraterrestrials could be in our solar system right now, with cloaking technology that hides them from our view while they patiently wait for us to mature. When scientists are confronted by multiple explanations for a phenomenon, they generally apply Occam's razor: Accept the simplest explanation with the fewest assumptions and reject the more fantastic and convoluted explanations. Perhaps the Galaxy is bustling with life and civilizations. But the simplest explanation, given the evidence in hand, points in the direction that we share the Galaxy with few others, or none at all.

The most optimistic ET claims are often put forth by the scientists who listen for radio signals from extraterrestrial intelligence. The search for extraterrestrial intelligence (SETI) represents a relatively inexpensive, experimental approach to this profound question. And although the chances of picking up a signal are slim, it certainly does no harm to look. But radio searches suffer because a negative result provides no information whatsoever about the preponderance of technological civilizations. Moreover, the discovery of quasars, pulsars, and the cosmic microwave background teaches us that if other civilizations inhabit the Galaxy, the first hint of their existence will likely come about by pure serendipity.

But until that happens, it seems prudent to conclude that we are alone in a vast cosmic ocean, that in one important sense, we ourselves are special in that we go against the Copernican grain. If so, humanity represents matter and energy evolved to its highest level; whereby a tiny part of the universe on a small rock orbiting an average star in the outskirts of an ordinary spiral galaxy has brought itself to a state of consciousness that can ponder the questions of how the universe, and life itself, began, and what it all means. □

Robert Naeye (rnaeye@astronomy.com) is an associate editor for ASTRONOMY. He hopes the folks who search for extraterrestrial intelligence soon prove this article wrong.

Although the existence of extraterrestrial civilizations won't be settled by popular vote, ASTRONOMY would like to know your opinion. Vote "Yes, other civilizations exist in the Milky Way Galaxy" or "No, we are alone in the Milky Way Galaxy" by letter (P.O. Box 1612, Waukesha, WI 53187), e-mail **(rnaeye@astronomy.com)**, or at our Web site **(http://www.kalmbach.com/astro/astronomy.html).**

Unwinding the Helix

Hubble reveals thousands of tiny, cometlike globules lurking in the interior of the Helix.

by Richard Talcott

The latest image from the Hubble Space Telescope shows unparalleled detail in the inner regions of the Helix Nebula (NGC 7293), a planetary nebula in Aquarius that probably ranks as the closest to Earth. Taken with Hubble's Wide Field and Planetary Camera 2 by astronomers C. Robert O'Dell and Kerry P. Handron of Rice University in Houston, the image resolves thousands of gossamer tendrils that look for all the world like tiny comets.

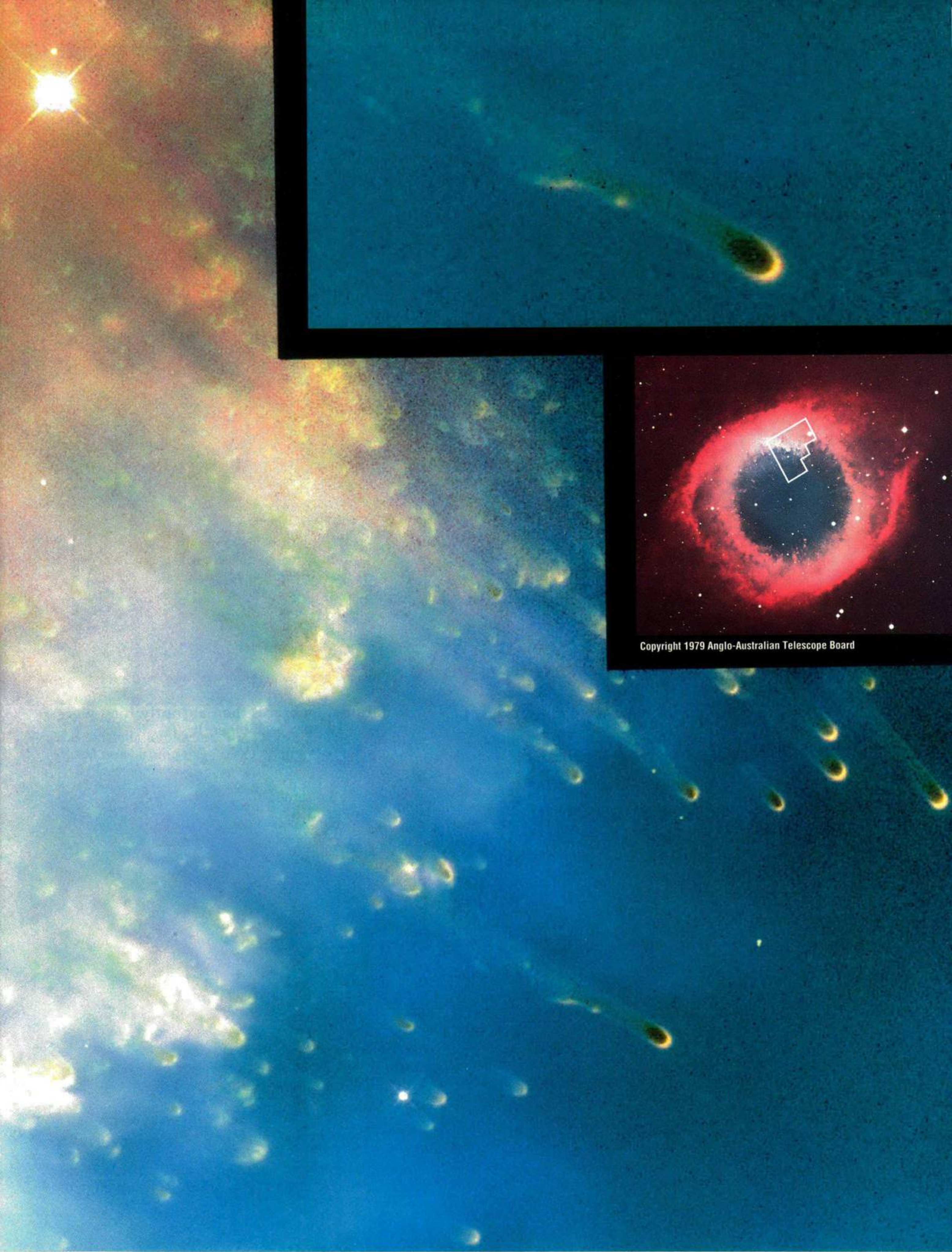
But the small apparent size of these "cometary knots" belies their true nature. At the Helix's distance of approximately 450 light-years, the "heads" of each knot have actual sizes of several billion kilometers (or roughly one hundred times the distance of Earth from the Sun) and the "tails" measure over 150 billion kilometers long, or about one thousand times the Earth-Sun distance. The knots still pale in comparison to the nebula itself, which spans over 15 trillion kilometers (1.6 light-years).

The most visible fragments lie along the inner edge of the nebula, a few trillion kilometers from the central star. All the cometlike tails point radially away from the center, giving the impression of spokes on a wheel. Although the spoke pattern had been seen in ground-based photos, the Hubble image shows a far greater number and for the first time lets astronomers see the structure of these objects.

The knots owe their existence to the continuing evolution of the nebula. Like all planetary nebulae, the Helix formed during the final stages in the life of a star that started with up to eight times the Sun's mass. As the star exhausted its nuclear fuel, it gently puffed off the distended outer layers of its atmosphere, forming the distinctive ringlike structure. Left behind at the center of the nebula was the hot core of the dying star, on its way to becoming a white dwarf. In the Helix's case, the nebula was born roughly 25,000 years ago.

The nebula is a relatively slow-moving, high-density gas cloud. At the same time, the surface of the 120,000-degree central star emits a much faster moving, lower density "stellar wind." As this gas slams into the smooth nebular cloud, the nebula fragments into small, dense fingerlike droplets. The faster moving wind flows around these globules, giving them their cometlike shape. Over time, the gaseous knots should dissipate into the cold blackness of interstellar space. □

C. Robert O'Dell, Kerry P. Handron (Rice University) and NASA



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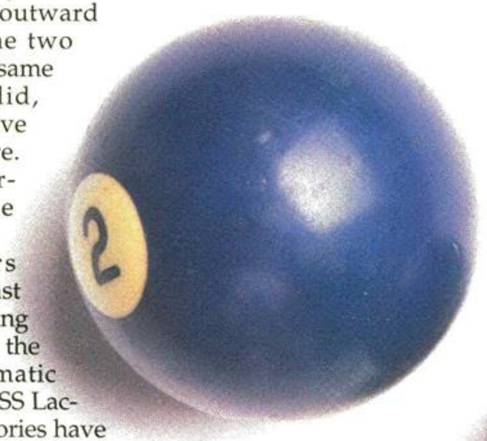
Cosmic Billiards

The mysterious star SS Lacertae seemed to be a perfectly normal eclipsing binary for decades, until one day astronomers discovered the eclipses had ceased.

by Stephen Schiller

It was nothing special, just a pedestrian binary star tucked away on the outskirts of an unremarkable open star cluster. For as long as astronomers had observed this system, the two stars orbited each other with precise regularity. However, by the early 1950s, the two stars that formed this binary system appear to have gone their separate ways.

This cosmic divorce came with no apparent warning — for many years the two were locked in a mutual gravitational embrace, then abruptly they were hurtling away from each other. It wasn't a messy divorce either. To most outward appearances, the two stars remain the same as they ever did, they just don't live together anymore. And just as perplexing, no one saw it coming.



Astronomers have spent the last several years trying to piece together the fate of the enigmatic binary known as SS Lacertae. Several theories have come and gone, but perhaps the one closest to the truth is also the most exotic: An unseen interloper may have collided with SS Lac, completely disrupting the system.

Stellar Eclipses

The apparent catastrophic demise of the binary system belies SS Lac's earlier, more-mundane existence. A seemingly normal member of NGC 7209, a fairly sparse open star cluster lying on the western edge of

Michael Carroll

the constellation Lacerta the Lizard, SS Lac's behavior raised no warning flags about what might be in store.

In fact, the star appears so ordinary at first glance that no one even recognized it as a binary system until this century. It wasn't until 1921 that German astronomer Cuno Hoffmeister discovered that SS Lac varied regularly in brightness. The pattern of the variations showed the characteristic signature of an eclipsing binary, proving the dual nature of the star.

In an eclipsing binary, two stars orbit each other in a plane that lies nearly edge-on as seen from Earth. Once during every orbit of the pair, the brighter star, called the primary, passes in front of the fainter secondary and blocks some or all of its light from view. Then when the stars reach the opposite ends of their orbits, the secondary star eclipses the primary. For most of the stars' orbital period, astronomers see the combined light from both stars, but the light dims slightly when the primary blocks the secondary from view and to a greater extent when the secondary eclipses the primary.

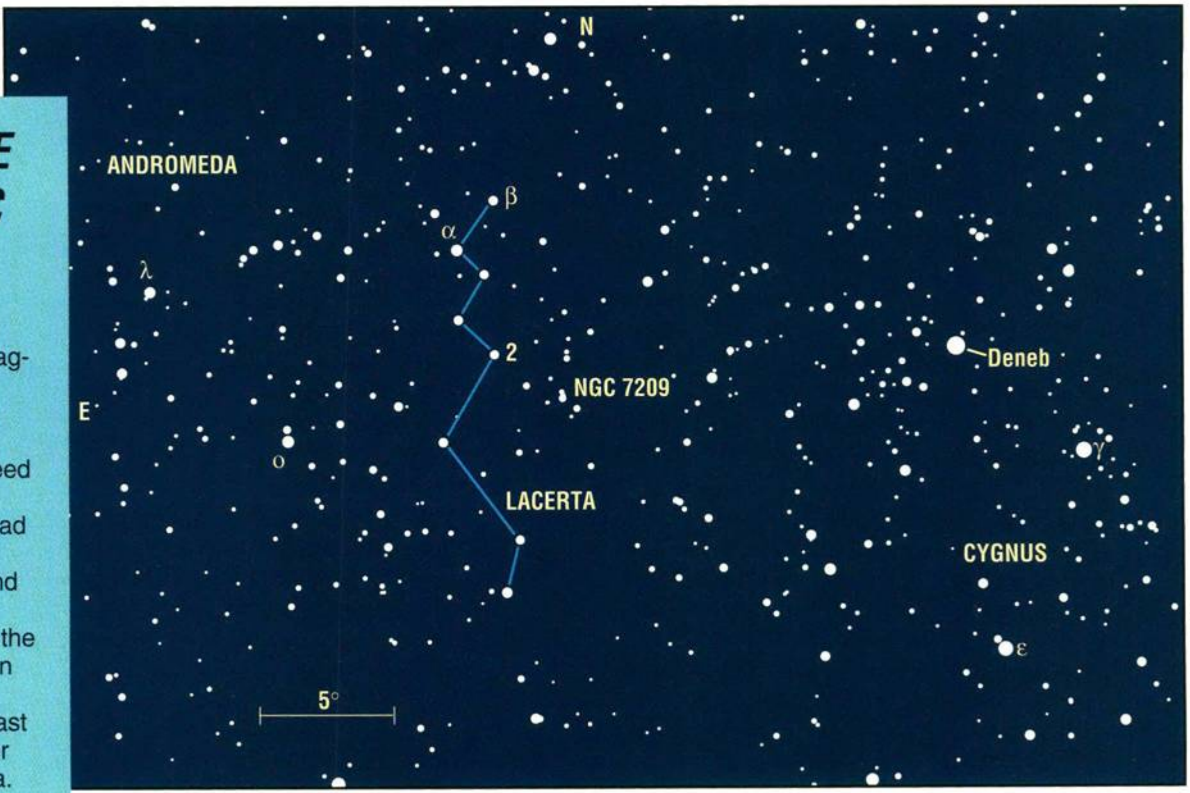
The best known eclipsing binary in the sky is Algol, the Demon Star in Perseus, whose brightness changes can be followed easily with the naked eye (see "Demon Variables," October 1992). Every 2 days, 20 hours, and 49 minutes, this 2nd-magnitude star fades by 1.2 magnitudes, dropping to just a third of its normal brightness. The secondary eclipse, with a light loss of a meager 3 percent, is much more difficult to see.

Following Hoffmeister's announcement on the nature of SS Lac, other astronomers began studying the binary. Using an extensive set of photographic plates taken at the Harvard College Observatory between 1890 and 1935, Raymond Dugan and Frances Wright showed that the stars revolved around each other once every 14 days and 10 hours. Unlike Algol, however, the primary and secondary eclipses were nearly equal in depth — the 10th-magnitude system faded by about 0.5 magnitude, or a little over a third in brightness, during both eclipses.

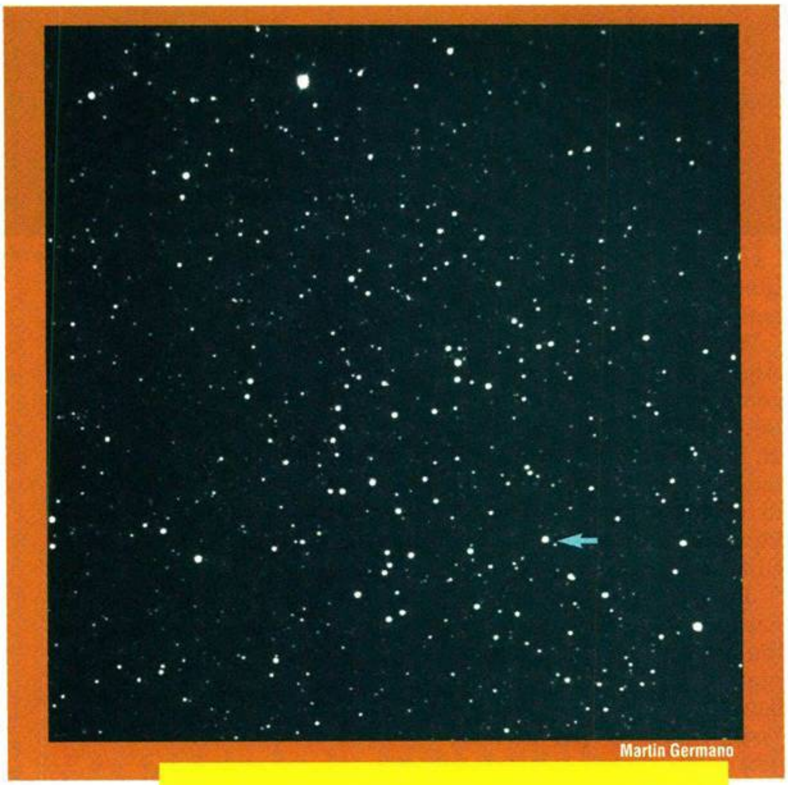
The equal light loss during both eclipses implied that the two stars had to have nearly identical surface temperatures. Otherwise, the system would appear dimmer when the hotter star (which emits more light from each unit of area) was blocked from view. Spectra of SS Lac showed that the two were main-sequence

LOCATE THE ENIGMATIC STAR

Although SS Lacertae glows dimly at 10th magnitude, anyone with a pair of binoculars or a small telescope can glimpse it. First you need to find the open star cluster NGC 7209. Head outside in the late evening during July and look high in the northeast, where you'll find the bright beacon Deneb in Cygnus. From there, head about 15° due east to NGC 7209, just over the border into Lacerta.



ASTRONOMY: Thomas L. Hunt



Martin Germano

ZERO IN ON SS LACERTAE

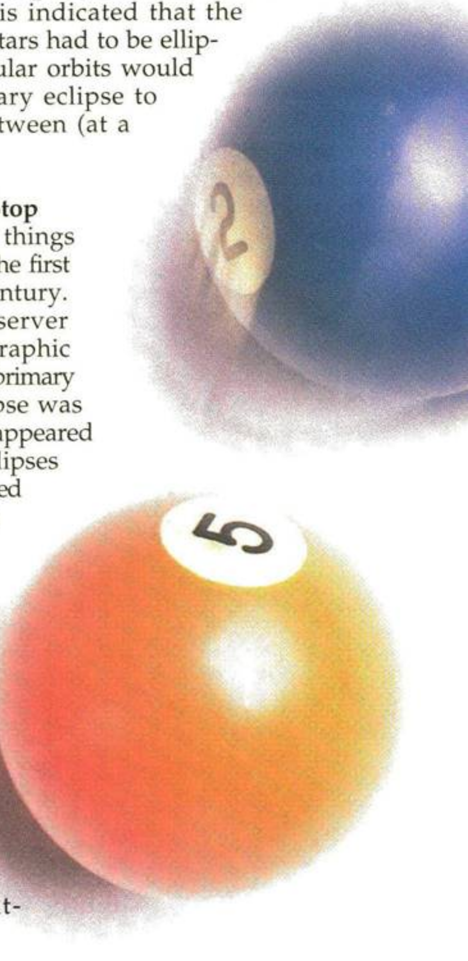
The cluster NGC 7209 contains roughly 50 stars spread over 25 arcminutes of sky, but none is as interesting as SS Lac. The former eclipsing binary appears as an inconspicuous dot (arrow) in the southwestern corner of the cluster.

stars of spectral type B9, implying masses about three times that of the Sun and surface temperatures around 11,000 kelvins.

Dugan and Wright also discovered that the secondary eclipse did not occur precisely halfway between primary eclipses, but instead at a phase of 0.57. This indicated that the orbits of the two stars had to be elliptical, because circular orbits would cause the secondary eclipse to occur halfway between (at a phase of 0.5).

The Eclipses Stop

That's the way things stood throughout the first half of the 20th century. Whenever an observer exposed a photographic plate at the time a primary or secondary eclipse was predicted, SS Lac appeared fainter. But the eclipses seem to have stopped around the middle of the century. Astronomers have observed the binary system both photographically and photoelectrically thousands of times in the past 45 years, but they have not detected any change in bright-



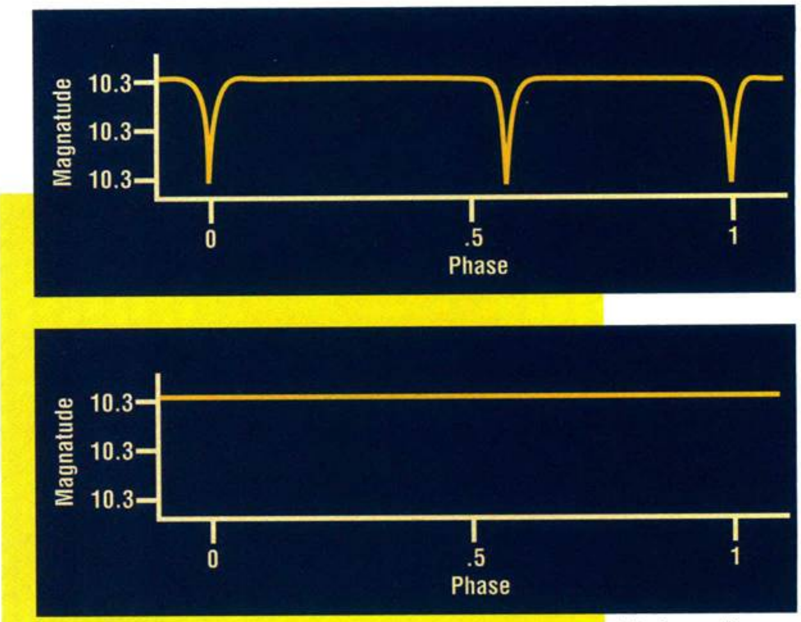
ness at any phase.

Obviously SS Lac no longer qualifies as an eclipsing binary, but could it still be a binary star? One way this could happen would be if the inclination of the system's orbit changed just enough so that eclipses no longer take place.

Astronomer Thomas Lehmann has analyzed many of the old photographic observations and concludes that the eclipses ceased around 1950 after slowly decreasing in intensity for several years. He developed a model for the decreasing eclipse depth by assuming that the system's orbital inclination had been changing slowly but steadily. In this scenario, the eclipses stopped once the orbits tilted far enough that the stars passed either above or below and not directly in front of each other. Lehmann found that he could fit the observations best if the orbits were exactly edge-on around the year 1911 and the inclination changed by approximately 0.18 degree per year.

This model can be tested by analyzing the spectrum of SS Lac. If the two stars still revolve around each other, their orbital motions would cause one star to move toward Earth as the other one moves away. These so-called radial velocities would show up in the spectrum as features that shift toward the blue or red, respectively. The radial velocities would be greatest if we viewed the system edge-on and drop to zero if the system appeared face-on.

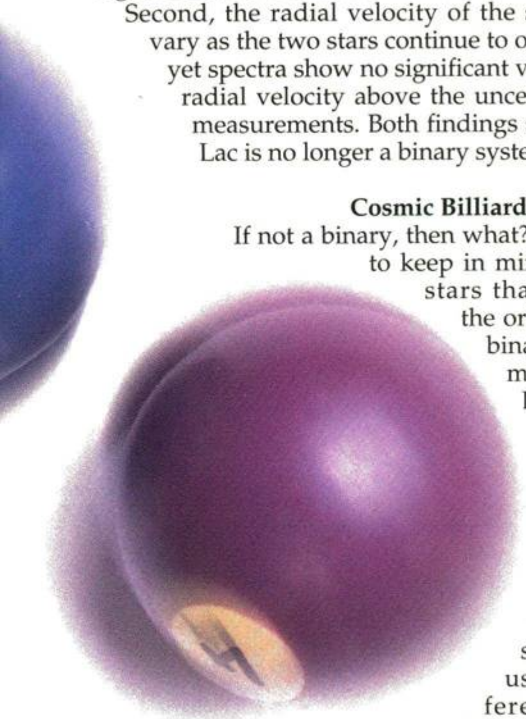
If the eclipses stopped because the binary system's orbital inclination had shifted slowly, spectra still would reveal the changing radial velocities by showing two sets of features. However, only one is seen. Second, the radial velocity of the system should vary as the two stars continue to orbit each other, yet spectra show no significant variations in the radial velocity above the uncertainties in the measurements. Both findings suggest that SS Lac is no longer a binary system.



After Raymond Dugan and Frances Wright

AN ECLIPSING BINARY

Early this century, SS Lac dimmed 0.5 magnitude at primary eclipse, phase 0 and 1, and secondary eclipse, phase 0.57 (top). Now the star stays the same brightness all the time (above).



Cosmic Billiards?

If not a binary, then what? The first thing to keep in mind is that both stars that belonged to the original eclipsing binary system still must be there. SS Lac now shines as brightly as the eclipsing binary did when not in eclipse, so the combined light of the two stars must still be reaching us. The key difference is that those two stars no longer appear to orbit each other.

Astronomers have far to go before understanding SS Lac, but they have come up with two scenarios that may help explain its unique behavior. Perhaps this was not just a binary system, but a system of three stars in orbit around one another. In that case, interactions among the trio could have caused the orbits to become suddenly chaotic, disrupting the entire system.

Even more intriguing is the possibility that another member of NGC 7209 collided gravitationally with SS Lac. This inconspicuous interloper could have flung the two stars apart, throwing the entire system for a loop. And despite the cosmic chaos you might expect from such a collision, there wouldn't yet be any obvious sign that this had happened.

The spectrum of SS Lac reveals only one star. That implies that the two stars must be separating perpendicularly to our line of sight or nearly so, otherwise the different radial velocities of the stars would cause two sets of spectral features. That in turn suggests that the two components should appear to separate rapidly from one another. But the cluster lies so far away, at a distance of roughly 3,000 light-years, that the motion would not yet give rise to an observable separation. After more than 40 years, however, the two stars may well be getting far enough apart to be identified by the Hubble Space Telescope's sharp eye.

Until that day comes, the stars of SS Lacertae will reveal their fates only through more and better spectra. Maybe then astronomers will be able to puzzle out what happened to the mysterious eclipsing binary that in the middle of the 20th century suddenly and unexpectedly ceased to exist. ☐

Stephen Schiller is a professor of physics at South Dakota State University in Brookings. He and Eugene Milone of the University of Calgary, Canada, have been observing SS Lac for more than ten years in hopes of solving this puzzle.

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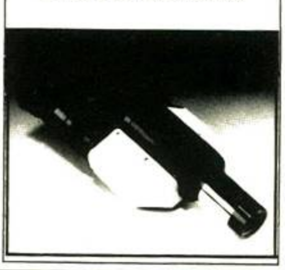

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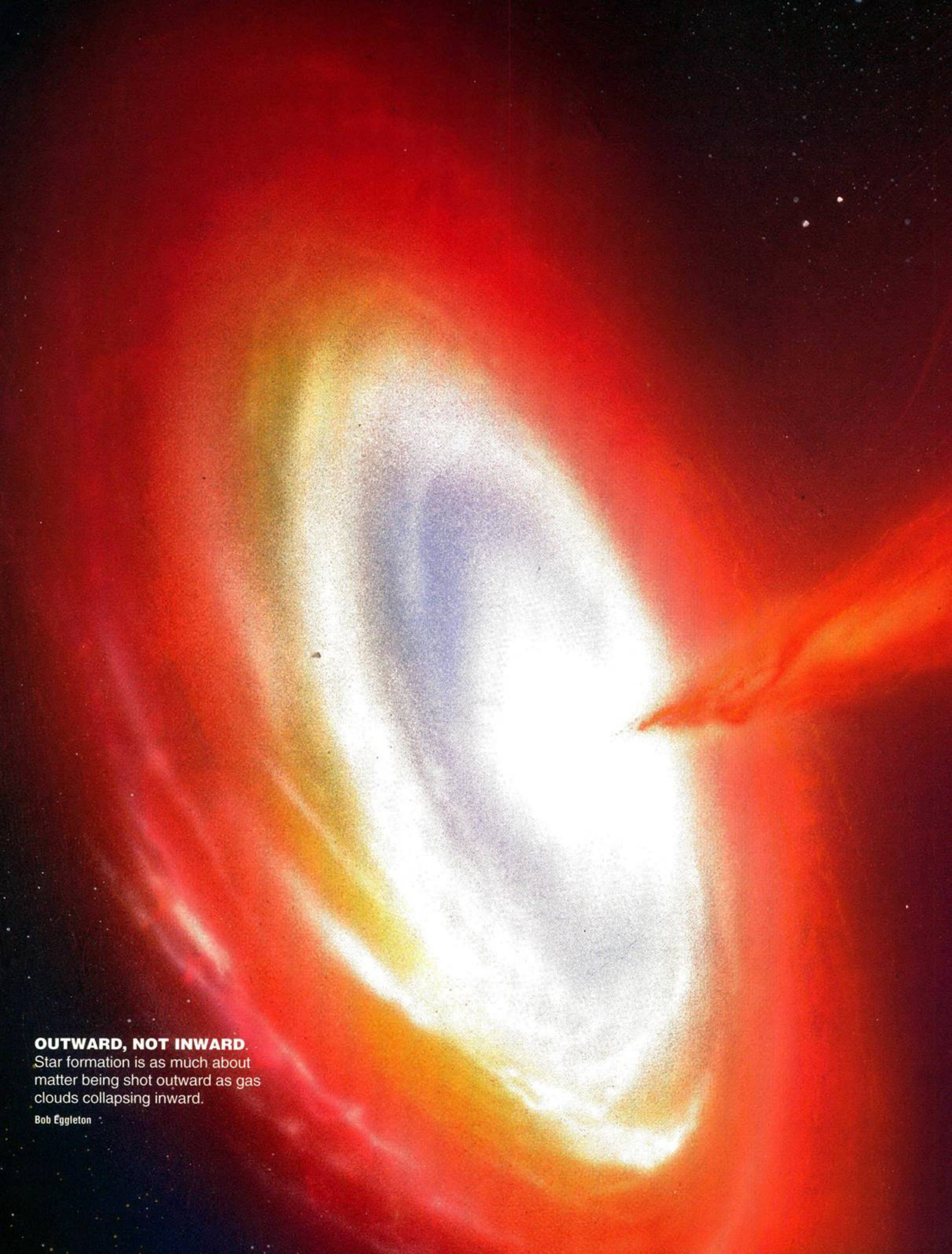
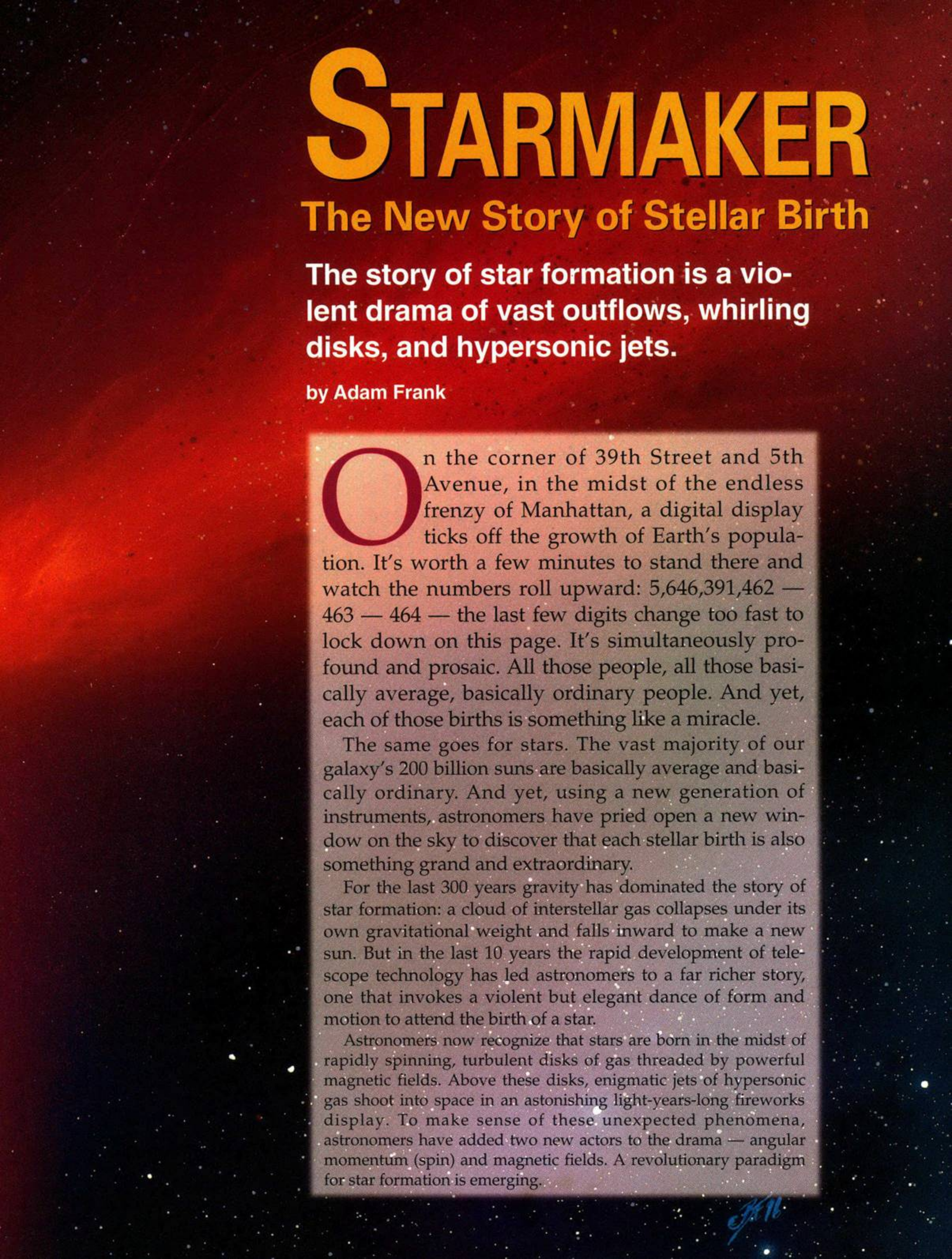


OUTWARD, NOT INWARD. Star formation is as much about matter being shot outward as gas clouds collapsing inward.

Bob Eggleton



STARMAKER

The New Story of Stellar Birth

The story of star formation is a violent drama of vast outflows, whirling disks, and hypersonic jets.

by Adam Frank

On the corner of 39th Street and 5th Avenue, in the midst of the endless frenzy of Manhattan, a digital display ticks off the growth of Earth's population. It's worth a few minutes to stand there and watch the numbers roll upward: 5,646,391,462 — 463 — 464 — the last few digits change too fast to lock down on this page. It's simultaneously profound and prosaic. All those people, all those basically average, basically ordinary people. And yet, each of those births is something like a miracle.

The same goes for stars. The vast majority of our galaxy's 200 billion suns are basically average and basically ordinary. And yet, using a new generation of instruments, astronomers have pried open a new window on the sky to discover that each stellar birth is also something grand and extraordinary.

For the last 300 years gravity has dominated the story of star formation: a cloud of interstellar gas collapses under its own gravitational weight and falls inward to make a new sun. But in the last 10 years the rapid development of telescope technology has led astronomers to a far richer story, one that invokes a violent but elegant dance of form and motion to attend the birth of a star.

Astronomers now recognize that stars are born in the midst of rapidly spinning, turbulent disks of gas threaded by powerful magnetic fields. Above these disks, enigmatic jets of hypersonic gas shoot into space in an astonishing light-years-long fireworks display. To make sense of these unexpected phenomena, astronomers have added two new actors to the drama — angular momentum (spin) and magnetic fields. A revolutionary paradigm for star formation is emerging.

A STELLAR NURSERY. Stars are born in vast clouds of gas, like this inner region of the famous Orion Nebula.

C. Robert O'Dell (Rice Univ.) and NASA

From Ashes to Stars

Stars are born from the ashes of stars. For some time astronomers have known that vast clouds of cold gas and dust spawn stars. "It's the ultimate act of recycling," says Alyssa Goodman of the Harvard-Smithsonian Center for Astrophysics. "Much of the matter in the clouds comes from older generations of stars in the form of supernovae and stellar winds." In time the atoms scattered by these dying stars coalesce into these giant clouds.

As the clouds collect more gas and dust they appear in optical telescopes as vast black walls. Visible light can't escape the giant clouds, but within this darkness something remarkable happens. Atoms collide and form complex molecules, stuff that would seem more natural under your kitchen sink than in the cold depths of space: water, alcohol, and ammonia. These molecules, and the copious dust grains, emit infrared light and millimeter-length waves. Fortunately for astronomers, infrared and millimeter radiation can escape the cloud.

To watch a star being born, astronomers needed telescopes that could detect infrared light and millimeter waves. Observing the sky in these wavelengths presents special challenges because of both atmospheric absorption and heat pollution. Nevertheless, astronomers have built succeeding generations of ever more powerful infrared and millimeter telescopes, allowing them to peer directly into the stellar womb.

Disks Everywhere

In the old "outside-in" story of star formation, which dates back to the early part of this century, astronomers tended to keep the picture simple: They imagined the spherical collapse of spherical clouds. But as astronomers began probing star-forming regions with their new infrared telescopes in the 1970s, they stumbled on something that forced them to imagine a richer menagerie of forms.

"When people looked at very young stars with their new infrared cameras, the results didn't make sense," says Len Kuhi of the University of Minnesota. "There was 10 to 100 times more infrared light coming from them than we expected." The only way astronomers could explain the infrared excess was to envision Frisbee-shaped disks of warm gas and dust surrounding the young stars (see "Solar Systems in the Making," March 1996). Light from the newborn stars heats the gas and dust, which re-radiates the energy in the infrared. (Material in some of these disks may later clump together to form planets.)

More sensitive infrared telescopes have made it clear that the story of star formation cannot be told without disks. "As of five years ago we thought 50 percent of all stars of a solar mass or less had disks around them," says Steve Strom of the University of Massachusetts. "With improved instruments and computing power we have been able to look much deeper into star-forming regions to see that nearly *all* stars form in the presence of disks."

The ubiquity of disks tells astronomers about the second major actor in the star formation drama: angular momentum. A fundamental relationship exists between the way things change size and how fast they spin. This law is called the "conservation of angular momentum." For example, when spinning ice skaters pull their arms in (making themselves "smaller"), they must spin faster to maintain the same angular momentum. When a spinning gas cloud collapses, it spins faster too. A spinning cloud, however, shrinks a million times more than an ice skater.

When a region of a cloud collapses, it always starts off with a small amount of spin — a residue left over from random motion of gas inside the larger cloud. "Anytime you start with something spherical and start it spinning, you end up with a disk," explains Suzan Edwards of Smith College. "It's just like the old-fashioned pizza places — where they take a ball of dough and spin it in the air to get a flattened crust."

As gas in the collapsing cloud falls inward, its rotational motion increases. When the gas reaches the center, it's whipping around so fast that it stops falling inward. The outward pull of the centrifugal force balances the inward pull of gravity. While this dance of gravity and angular momentum keeps the planets locked in their orbits around the Sun, the whirling motion creates a physical barrier that keeps the gas from settling down into a new star. Edwards coined the term "angular momentum crisis" to describe this barrier to star formation.

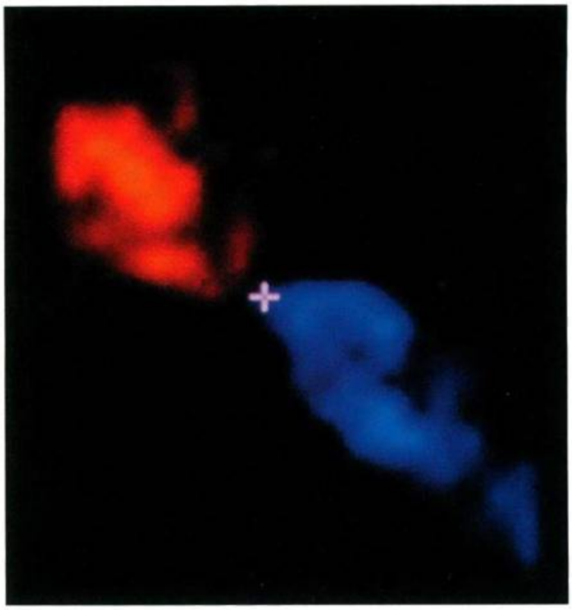
The disks are nature's way over this barrier. Somehow the gas in the disk has to shed its angular momentum and slow down. Gravity can then drag the gas inward in a long, contracting spiral that leads to the inner edge of the disk. In the final act of the drama, the gas drops down into the center of the cloud, forming a new star. As Steve Strom puts it, "You shouldn't think of a star starting at a large radius and contracting. Instead, think of these very tiny seeds that are built up by accretion of material which first passes through the disk." Because these gaseous space Frisbees feed new matter to stars, astronomers call them "accretion disks."

From Inward to Outward

Recognizing that stars are born from disks that are first born from clouds completed a reenvisioning of the collapse process that began with a seminal 1977 paper by Frank Shu of the University of California at Berkeley. Shu realized that star formation wasn't just a matter of a big cloud shrinking to form a star. Instead it went the other way around. Shu visualized star formation occurring from the inside-out rather than from the outside-in as stars in the center of disks slowly grow outward.

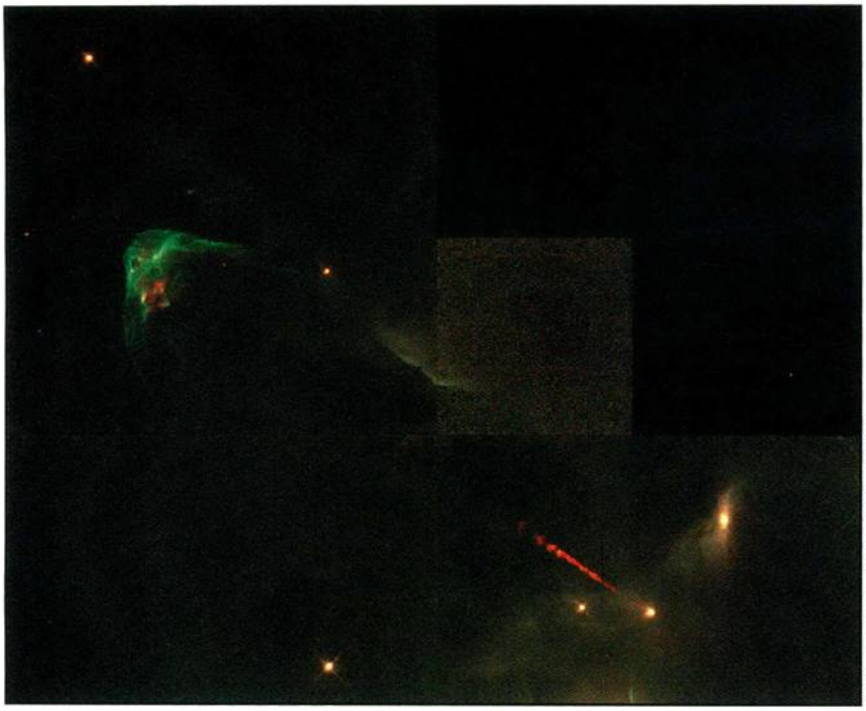
As powerful a vision as this was, it could not predict what was to follow. In the late 1970s, astronomers started observing bright, mysterious knots of light that often appeared close to dark star-forming clouds. These Herbig-Haro objects (named for the astronomers who discovered them, George Herbig and Guillermo Haro) emitted so much visible light that some scientists thought they were the much sought-after newborn stars.

But after watching the bright knots over a period of years, astronomers made a startling discovery. The light from Herbig-Haro objects came from shock waves generated by clumps of gas punching their way through the surrounding gas at fantastic speeds. The Herbig-Haro objects



Ronald Snell (Univ. of Massachusetts)

MOLECULAR OUTFLOWS containing prodigious quantities of gas zoom away from newborn stars.



Jeff Hester (Arizona State Univ.) and NASA

SHOOTING STAR. Astronomers now realize that hypersonic jets are a natural consequence of star birth.

Mark McCaughrean (Max-Planck-Inst.), C. R. O'Dell (Rice Univ.), and NASA

EDGE-ON DISK. The Hubble Space Telescope recently imaged accretion disks surrounding 160 protostars in the Orion Nebula. This discovery bolsters astronomers' theory of star formation.

were in motion and, even more startling, their motions could always be traced back to a hidden embryonic star. This was completely unexpected and it forced astronomers to confront a strange paradox: Star formation was supposed to be about matter collapsing *inward*. Instead, Herbig-Haro objects were being shot *outward*.

In the mid-1980s the picture grew even more complicated as Herbig-Haro objects gave way to Herbig-Haro jets. Rather than isolated clumps, astronomers found that Herbig-Haro objects are actually knots embedded in narrow jets of gas. The properties of the jets are almost too fantastic to believe. Traveling faster than 1 million kilometers per hour, the jets can launch more than a trillion trillion metric tons of gas into space every day. The Hubble Space Telescope has now added a new dimension to the study of the jets, allowing astronomers to follow the streams almost all the way down to the stars themselves (see "Hubble Observes the Violent Birth of Stars," October 1995).

Even though jets can span 10 light-years of space, Hubble has shown astronomers that these jets originate very close to the stars and their disks. The speed, power, and size of these jets is astonishing. They are akin to a garden hose shooting a tight stream of water 20 miles into the sky.

Millimeter-wave telescopes complicated the picture when they revealed vast quantities of cold molecular gas flowing outward, away from young stars. It soon became clear that almost all nascent stars were shooting "molecular outflows" into space.

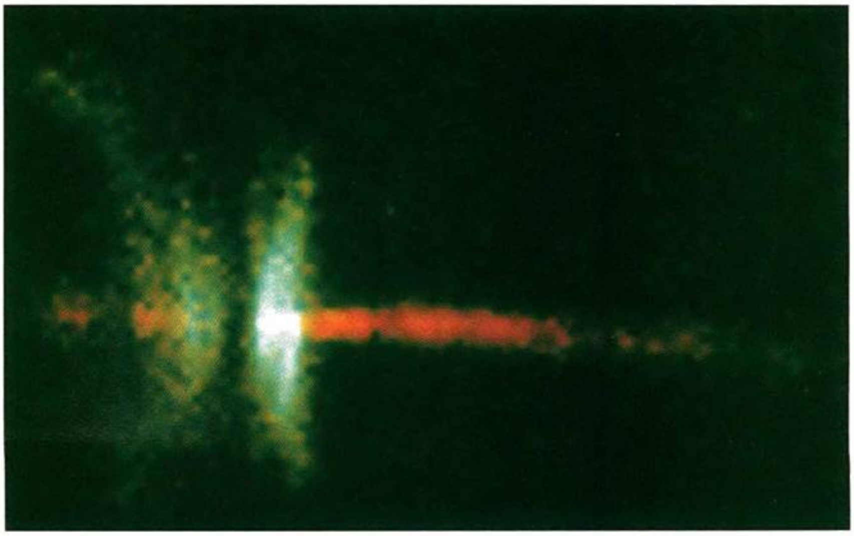
The molecular outflows are as spectacular as the jets. Though they move much more slowly than the jets, the outflows can contain hundreds of solar masses. That is more mass than is locked up in the young stars, so the matter in the molecular outflows must originate in the surroundings. "While we can't say for sure yet, it does appear that giant outflows are driven by the jets," explains Jon Morse of the University of Colorado. "The molecular gas may be material that has been pushed out of the way or swept up as the jet plows through the surrounding cloud."

Since the 1980s the increasing sophistication of optical and longer wavelength telescopes has forced astronomers to come to terms with the new actors in the star formation drama. Jets and molecular outflows are as much a part of star formation as collapse and infall. But why would nature make stars out of a paradox? How do the jets and outflows form, and what purpose do they serve? These questions fuel intense debate among astronomers and there is, as yet, no definitive answer. The solution to the mystery, however, may lie in the connection between the accretion disks and the third actor in the star formation drama: magnetic fields.

Magnetic Machinations

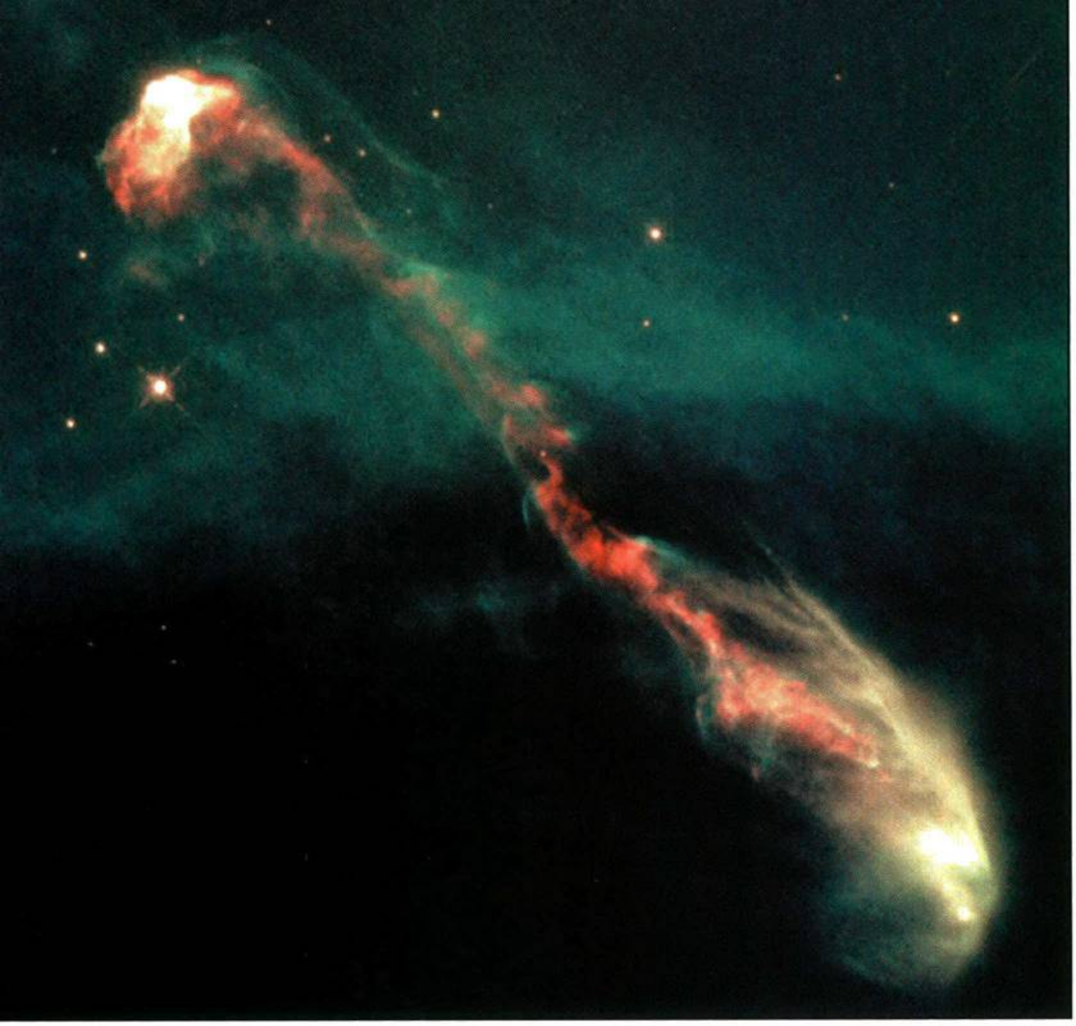
Magnetic fields are everywhere in space. Lines of magnetic force thread the giant molecular clouds too. When parts of the cloud collapse, the field lines get dragged down and become embedded in the disks. Astrophysicists hope that an elegant new theory can solve the inflow/outflow paradox by uniting the disks and jets in an intricate dance of matter, magnetism, and motion.

Imagine powerful magnetic fields threading an accretion disk like rigid wires sticking up and out of a rotating phonograph turntable. As the gas in the disk spins, these "magnetic wires" get whipped around too. The gas atoms connected to the field are like beads strung on the wires. In an accretion disk, the field may bend away from the center of the disk. If this happens, then, as the wires whip around, an outward, centrifugal force on the beads lifts them up off the disk and flings



Chris Burrows (STScI) and NASA

A DISK AND JET are the end result of the tumultuous star formation process. This Hubble Space Telescope image shows a protostar 450 light-years away.



SPANNING HALF A LIGHT-YEAR, a Herbig-Haro jet stretches across space. The newborn star that produced the jet is at the lower right, embedded in its stellar nursery. A counterjet going in the opposite direction is obscured by gas clouds.

Jon Morse (Univ. of Colorado), Bo Reipurth (European Southern Obs.), et al., and NASA

them out along the wires into space. The magnetic fields channel the beads into a flow running perpendicular to the disk.

By tapping the enormous energy locked in the spinning motion of the gas, the magnetic field can launch a powerful wind off the disk that can then be redirected into a jet. Because the winds are driven by rotation, they carry angular momentum and matter away from the disk. By providing a way to shed excess spin, these "disk-winds" may solve two problems at once. They can power the jets and, perhaps, solve the angular momentum crisis by giving the matter in the disk a way to slow down enough to make the final plunge from the disk to the star.

Astronomers have different versions of the disk-wind theory. In some, the wind originates throughout the entire disk. In others, it is only the inner regions of the disk and the star that drive the wind. While the mathematical details of the theories can be horribly complicated, there is a delightful economy and elegance about the idea that has won it many converts among astronomers. The disk-wind theory unites the disparate actors of star formation — clouds, disks, jets, and outflows — into a coherent whole. The presence of magnetic fields in the disk may virtually force the existence of outflows. When a theory pulls so many different phenomena together with such seemingly effortless elegance, astronomers sense that they have grasped something physically profound and fundamental.

All Things Bright and Beautiful

There is a particularly human poetry in the new story of star formation. In the paradox of infalling and outflowing gas streams, nature challenged astronomers to find higher ground and build a synthesis uniting star formation's disparate faces. Through a close dialogue with the night sky, carried out in the language of observation and theory, astronomers rose to that challenge and transformed a confusion of facts into a singularly coherent account of stellar birth.

While this new story has not yet been fully told, the central image of disks, winds, and jets attendant to the birth of stars is certain to become the guiding paradigm for at least the next generation of astronomers. With the discovery of planets orbiting nearby stars, the establishment of star formation's new paradigm could not be any more timely or urgent. In their efforts to study star formation, astronomers have passed though a story much like that of a young star: a journey from chaos to order and from darkness to light. ☐

Adam Frank is an astrophysicist at the University of Minnesota who studies star formation, jets, and outflows. In 1995 he was awarded the prestigious Hubble Fellowship by NASA.

ALMANAC

Dog Day evenings usher in gas giant planets, both bright and dim. Climbing the east is that most seasonal of icons, the Summer Triangle.

by Jeff Kanipe

Highlights

by Alister Ling

Date	Event
4	Jupiter's Midsummer Opposition . . .(p. 65)
18	Month of the Distant Giants (p. 65)

all month:

First Views:
Seeing Double in Cygnus . . . . . .(p. 63)
Observer's Challenge:
Dog Days of Pluto . . . .(p. 64)
Month of the Distant Giants . . . .(p. 65)
Comet Kopff Digs South . . . .(p. 66)
Pallas Arcs Past Arcturus . . . . .(p. 66)
Gazetteer to Noctilucent Clouds . . . .(p. 67)

Do not go gentle into the buggy nights of summer. Take some stout insect repellent with you, and a pair of hand-held binoculars for added light-gathering power. Find a place with more sky than trees, more starlight than streetlight, more quiet than ruckus, and face west toward the dimming of the day. What's the brightest star you can see?

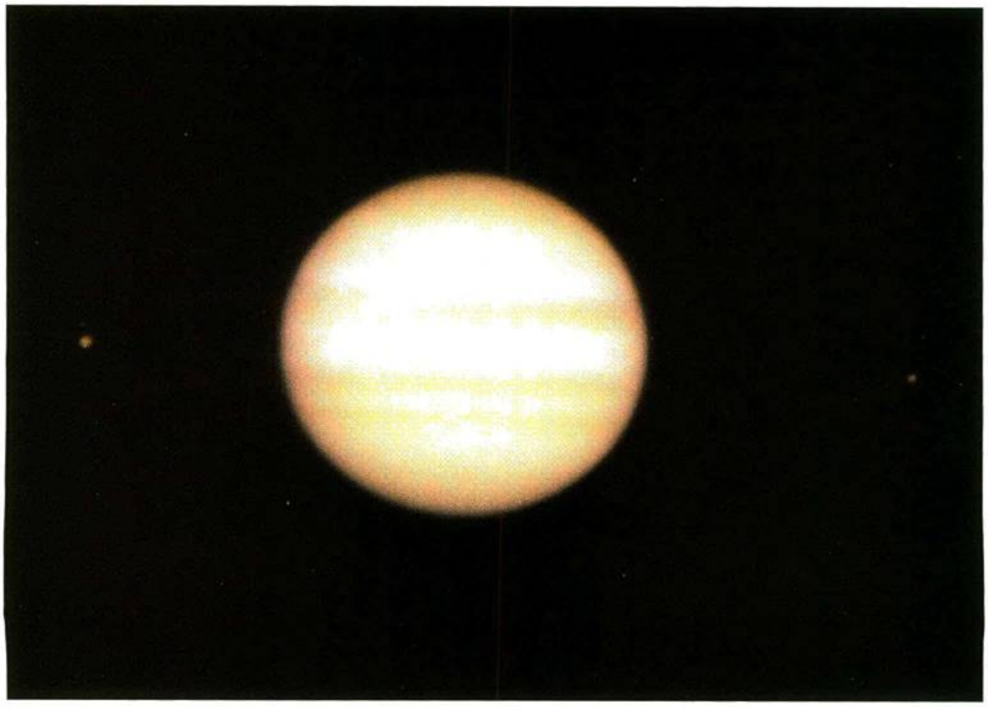
Chances are it will either be Regulus in Leo, which is nearly due west and very low in the sky, or Spica in Virgo, lying farther south but a bit higher up. Though it is high summer, these luminaries aren't quite the last stars of spring. For still fairly high up, and situated decidedly farther to the west than last month at this time, is reddish Arcturus in Bootes the Herdsman. As bright as Arcturus is — it is the fourth brightest star in the night sky — this may be the first star you see tonight.

There are no planets in the western evening sky, though **Mercury** finds its way there toward the end of the month. Even then, however, the ecliptic's shallow angle to the horizon makes Mercury very difficult to see in the Northern Hemisphere. The apparition is more favorable to our mates down under.

High in the southeast at sunset is a planet no one should have trouble seeing, **Jupiter**, lying in eastern Sagittarius, just above the handle of the "teapot" asterism. On July 4, the giant planet reaches opposition, when it is exactly opposite the Sun in our sky. Jupiter rises at sunset, lies due south at midnight, and sets at sunrise. Opposition marks the start of evening viewing of the planet for the next several months. Its large apparent diameter, due to its proximity to Earth at this time, ensures that those with small telescopes should be able to observe a nightly display of changing cloud patterns.

Located in the thick of the Milky Way, Jupiter lies near Pi (π), Xi (ξ), and Omicron (o) Sagittarii, the main stars of Sagittarius' "teaspoon" asterism. The planet passes 0.14° south of the magnitude-9.2 globular cluster NGC 6717 on July 3 and 0.12° south of Nu^1 (ν^1) and Nu^2 Sagittarii on July 5. In the after-midnight sky of July 28, the waxing gibbous Moon lies about 6 ½° to the north.

If you're at a dark sky site, try looking about 12° due north of Jupiter for **Comet Hale-Bopp** in Scutum the Shield. If all goes



Don Parker

EVENING KING. Jupiter dominates the night sky all month from a Milky Way throne in eastern Sagittarius. Check out the *planet's cloud* decks and four large moons with a low-power telescope.

JULY

1 The Moon passes 5° north of Jupiter, 6 a.m. EDT
The Moon is at perigee (222,419 miles from Earth), 6:12 p.m. EDT
Venus is stationary, 8 p.m. EDT

4 Comet Hale-Bopp is at opposition
Jupiter is at opposition, 8 a.m. EDT (page 65)

5 Earth is at aphelion (94.5 million miles from the Sun), 2 p.m. EDT

7 The Moon passes 3° north of Saturn, 2 a.m. EDT
Last Quarter Moon is at 2:55 p.m. EDT

11 Mercury is in superior conjunction, 5 a.m. EDT
Comet Kopff is at opposition (page 66)

12 The Moon passes 0.4° north of Venus, 5 a.m. EDT
The Moon passes 5° south of Mars, 7 p.m. EDT

15 New Moon is at 12:15 p.m. EDT

16 The Moon is at apogee (252,648 miles from Earth), 9:34 a.m. EDT

17 Venus is at greatest brilliancy (magnitude –4.5), 5 a.m. EDT
Asteroid Victoria is at opposition

18 Neptune is at opposition, 2 p.m. EDT (page 65)

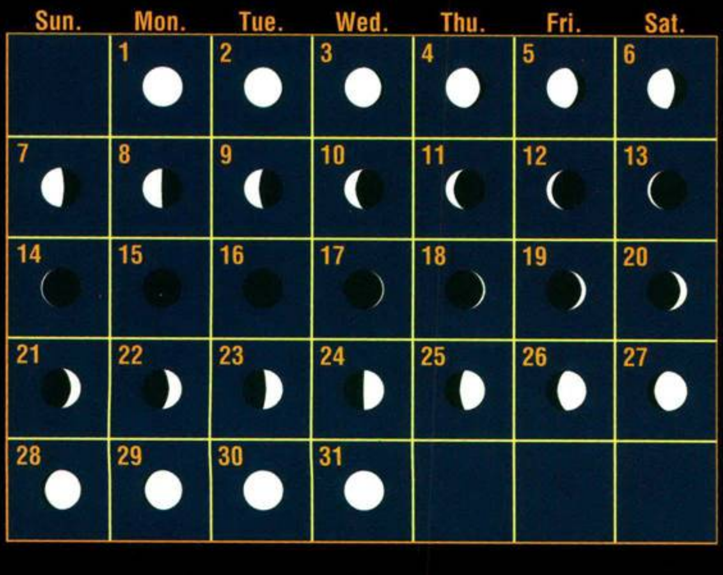
19 Saturn is stationary, 8 p.m. EDT

23 First Quarter Moon is at 1:49 p.m. EDT

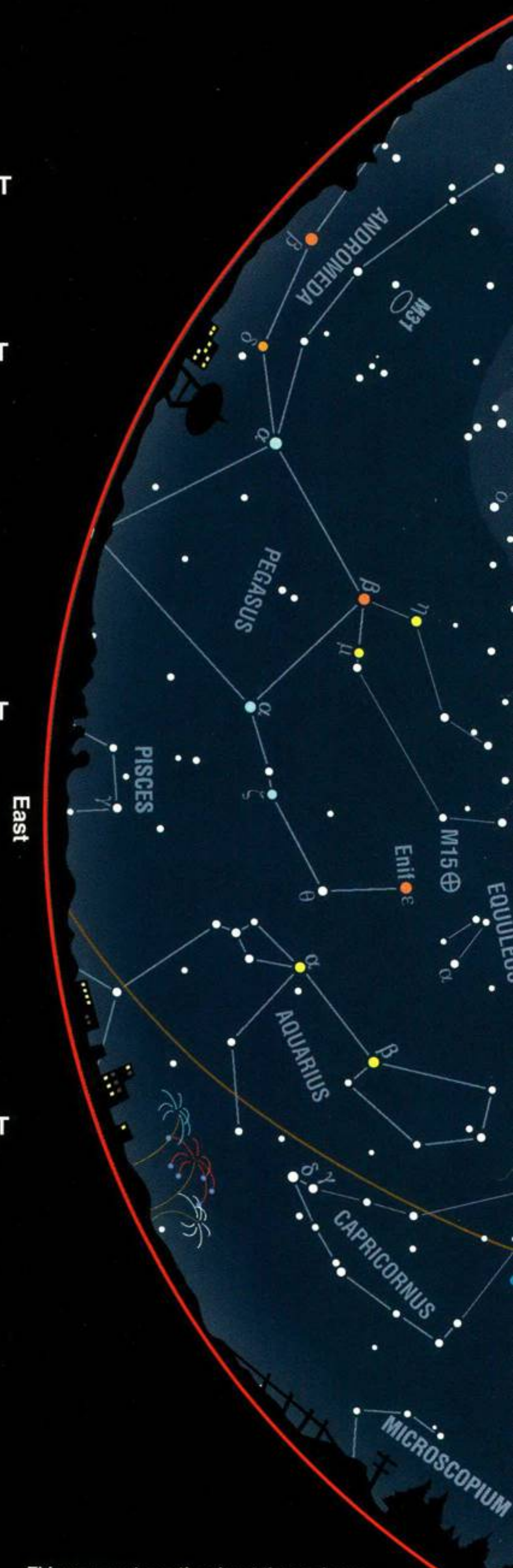
25 Uranus is at opposition, 3 a.m. EDT (page 65)

28 The Moon passes 5° north of Jupiter, noon EDT

30 The Moon is at perigee (221,797 miles from Earth), 3:36 a.m. EDT
Full Moon is at 6:35 a.m. EDT

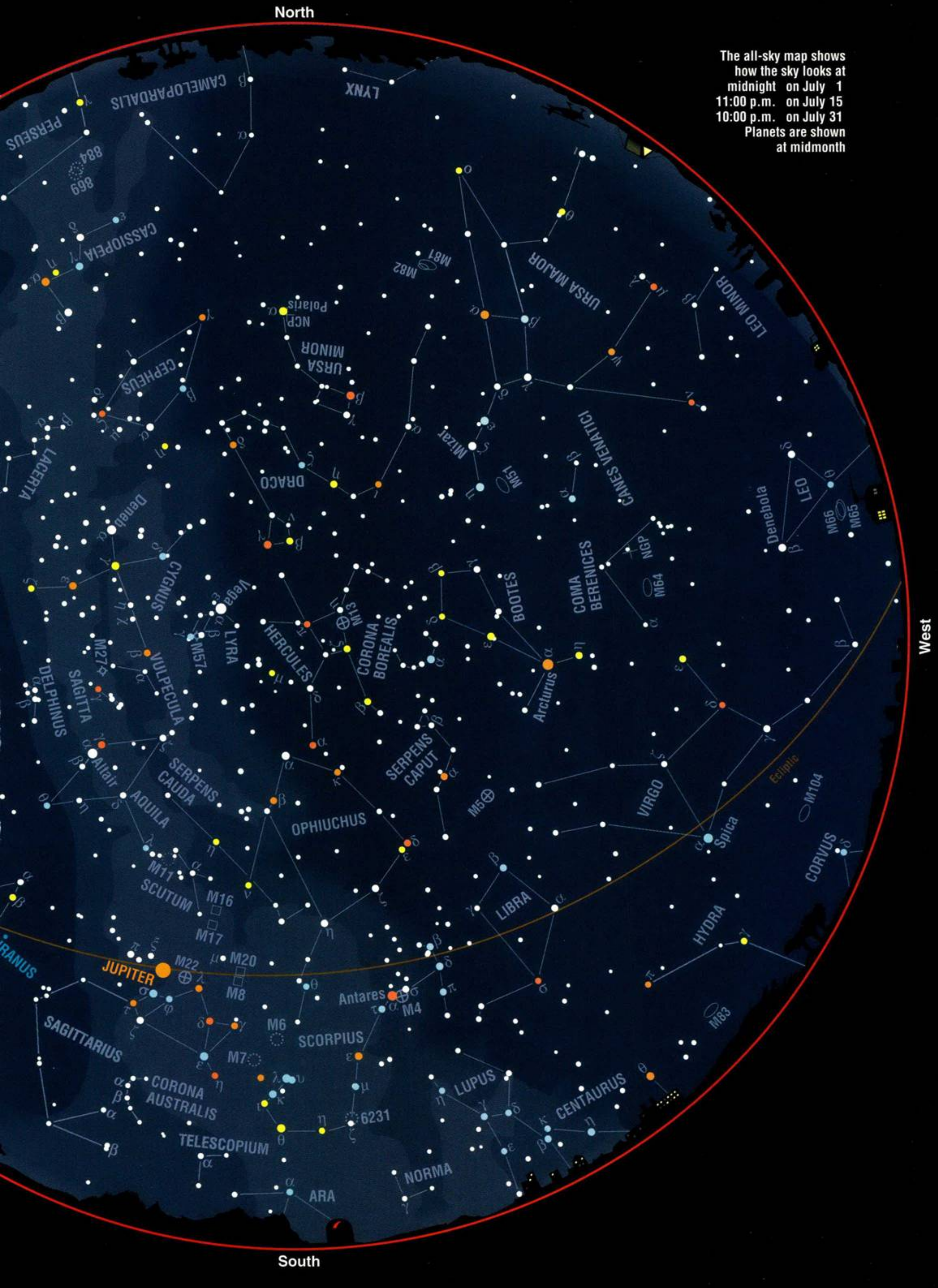


Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

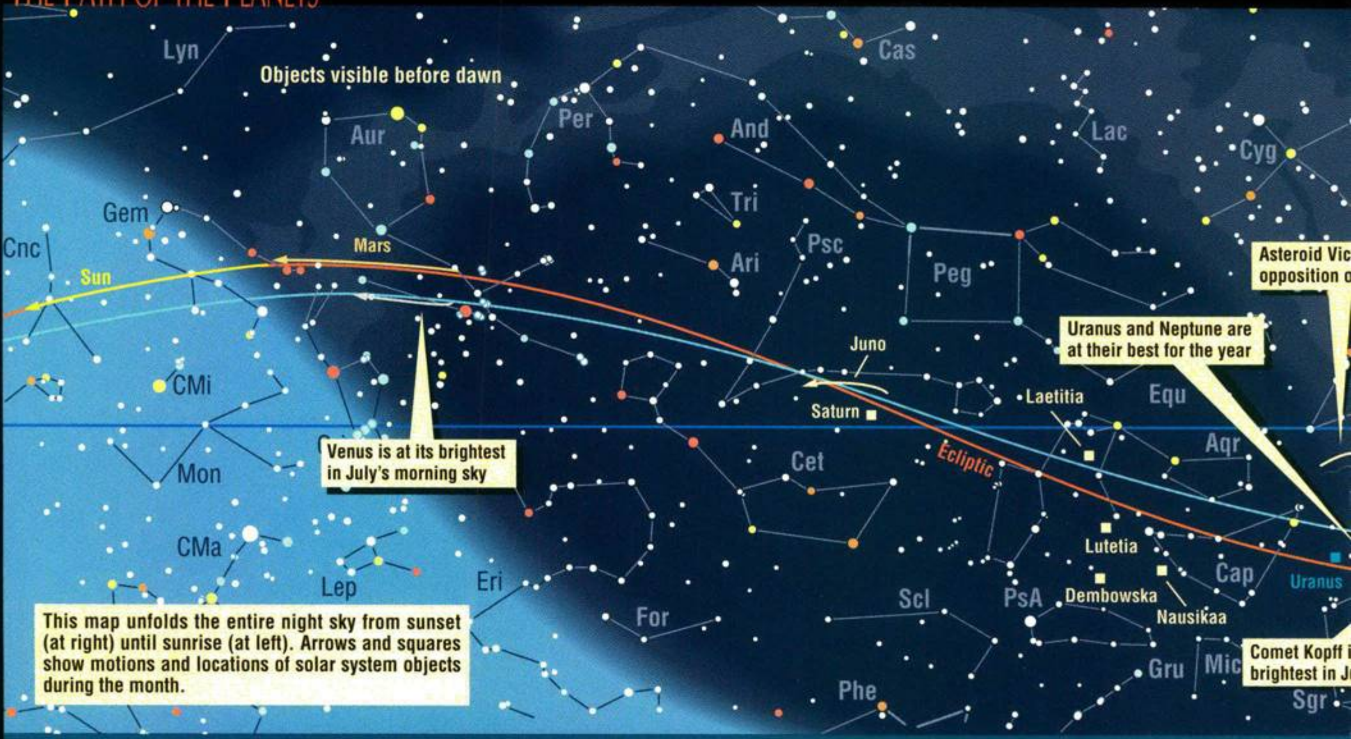


This map portrays the sky at times shown in the upper right corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

The all-sky map shows
how the sky looks at
midnight on July 1
11:00 p.m. on July 15
10:00 p.m. on July 31
Planets are shown
at midmonth


North
South
West
LYNX
CAMELOPARDALIS
PERSEUS
884
869
CASSIOPEIA
URSA MAJOR
M81
M82
LEO MINOR
Polaris
NCP
URSA MINOR
CEPHEUS
LACERTA
DRACO
Mizar
M51
CANES VENATICI
LEO
Denebola
M66
M65
Deneb
CYGNUS
Vega
LYRA
M57
M13
HERCULES
CORONA BOREALIS
BOOTES
COMA BERENICES
NGP
M64
Arcturus
M27
VULPECULA
SAGITTA
DELPHINUS
Altair
AQUILA
SERPENS CAUDA
SERPENS CAPUT
M5
OPHIUCHUS
VIRGO
Ecliptic
M104
Spica
CORVUS
M11
SCUTUM
M16
M17
LIBRA
HYDRA
URANUS
JUPITER
M22
M20
M8
Antares
M4
M6
SCORPIUS
M7
M83
SAGITTARIUS
CORONA AUSTRALIS
LUPUS
CENTAURUS
6231
TELESCOPIUM
NORMA
ARA

THE PATH OF THE PLANETS


Lyn
Cas
Aur
Per
And
Lac
Cyg
Gem
Tri
Cnc
Mars
Ari
Psc
Sun
Peg
Juno
CMi
Saturn
Laetitia
Equ
Mon
Cet
Ecliptic
Aqr
CMa
Lutetia
Lep
Eri
Cap
Uranus
Scl
PsA
Dembowska
Nausikaa
For
Gru
Mic
Phe
Sgr

Objects visible before dawn

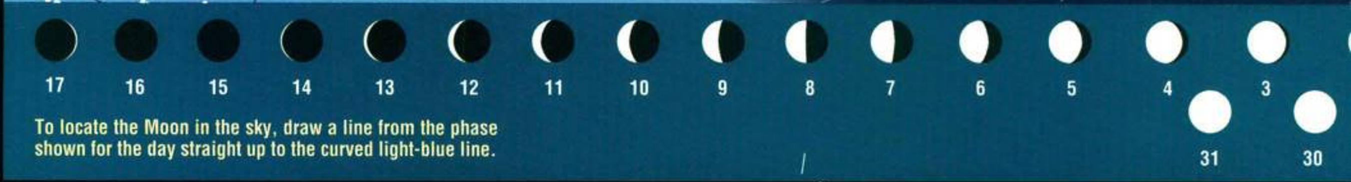
Asteroid Vic
opposition o

Uranus and Neptune are at their best for the year

Venus is at its brightest in July's morning sky

This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and squares show motions and locations of solar system objects during the month.

Comet Kopff i
brightest in J


17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
31
30

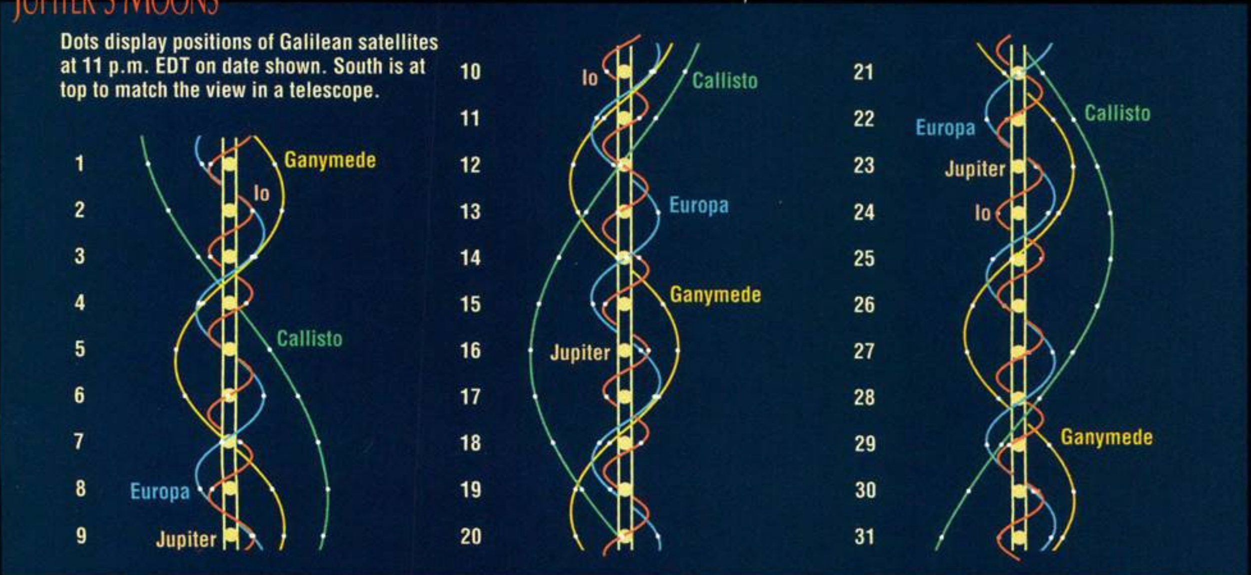
To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved light-blue line.

10"

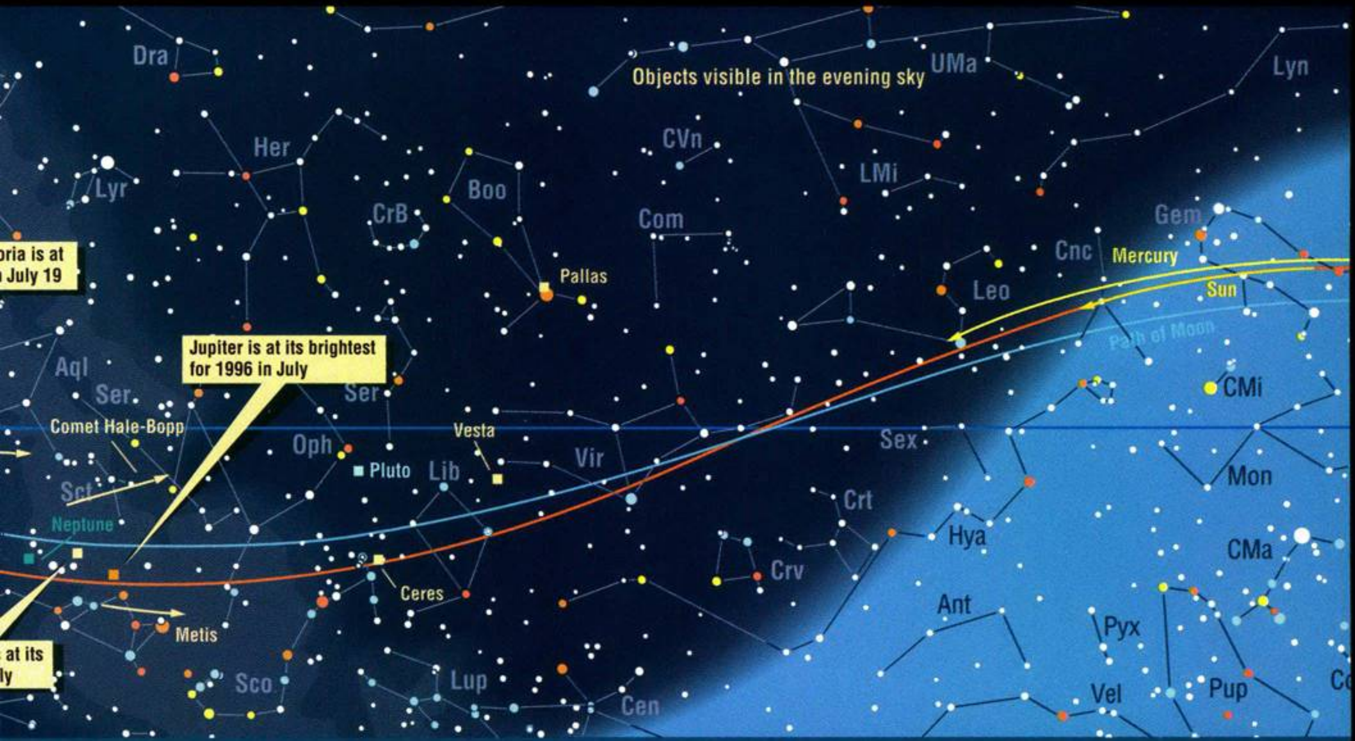
S
W — E
N

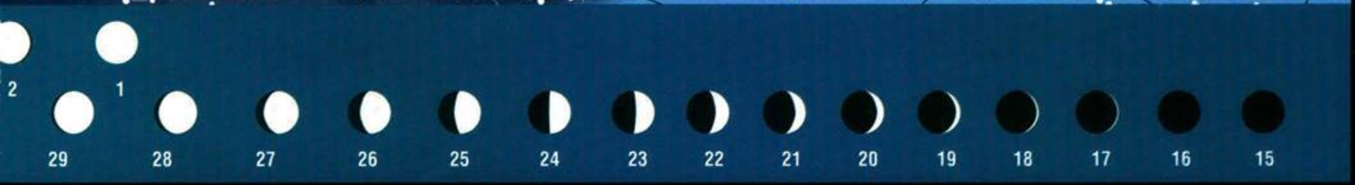
PLANETS	MERCURY	MERCURY	VENUS	VENUS	MARS
Date	July 1	July 31	July 1	July 31	July 15
Magnitude	–1.2	–0.4	–4.4	–4.4	1.5
Angular Size	5.5"	5.6"	48.0"	30.3"	4.1"
Illumination	87%	80%	12%	38%	97%
Distance (AU) from Earth	1.227	1.208	0.348	0.551	2.293
Distance (AU) from Sun	0.316	0.417	0.728	0.728	1.503
Right Ascension (2000.0)	5h48.6m	9h59.6m	4h43.7m	5h35.9m	5h28.3m
Declination (2000.0)	23°18'	13°28'	18°0'	18°52'	23°31'

JUPITER'S MOONS



Dots display positions of Galilean satellites at 11 p.m. EDT on date shown. South is at top to match the view in a telescope.


Objects visible in the evening sky
Dra
UMa
Lyn
Her
CVn
Lyr
Boo
LMi
CrB
Com
Gem
Cnc
Mercury
Pallas
Leo
Sun
oria is at
July 19
Jupiter is at its brightest for 1996 in July
Path of Moon
Aql
Ser
CMi
Ser
Comet Hale-Bopp
Vesta
Sex
Oph
Vir
Pluto
Lib
Mon
Sct
Crt
Neptune
Hya
CMa
Crv
Ceres
Ant
Metis
Pyx
at its
ly
Sco
Lup
Vel
Pup
Cen
Co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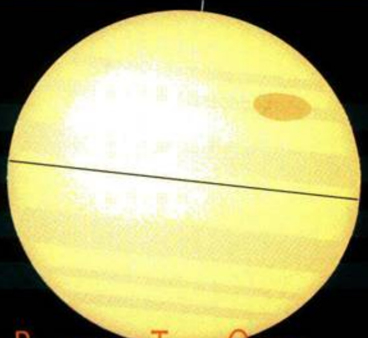
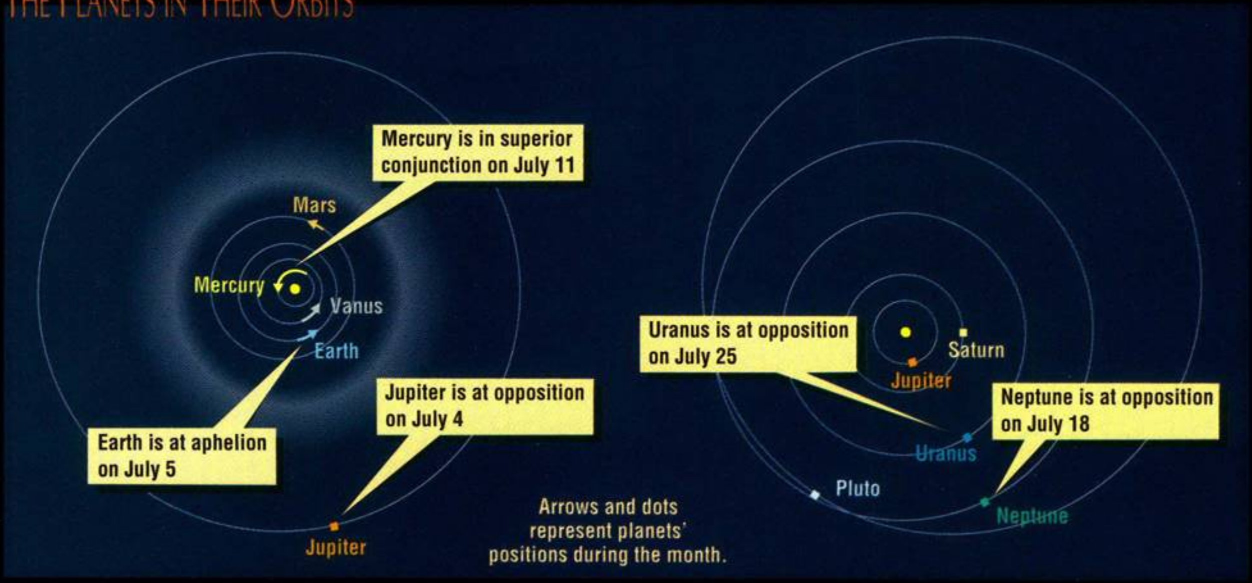


JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
July 15	July 15	July 15	July 15	July 15
−2.7	0.8	5.7	7.9	13.7
47.0"	18.1"	3.8"	2.3"	0.1"
100%	100%	100%	100%	100%
4.199	9.200	18.773	29.146	29.297
5.199	9.521	19.774	30.161	29.913
18h49.9m	0h31.1m	20h22.0m	19h53.7m	16h04.6m
−23°02'	0°46'	−20°04'	−20°22'	−7°19'

THE PLANETS IN THEIR ORBITS


Mars
Mercury
Vanus
Earth
Jupiter
Saturn
Jupiter
Uranus
Pluto
Neptune

Mercury is in superior conjunction on July 11

Earth is at aphelion on July 5

Jupiter is at opposition on July 4

Uranus is at opposition on July 25

Neptune is at opposition on July 18

Arrows and dots represent planets' positions during the month.

as expected, the comet will reach naked-eye visibility in late July or early August. These predictions, however, don't preclude Comet H-B from becoming visible a little earlier. You should have no problem seeing it in binoculars.

Clearing the southeastern horizon around 10:30 p.m. local time is the faint wing-shaped constellation Capricornus the Sea Goat. Off the west side of Capricornus is a region of sky harboring two of the solar system's remote giants: **Uranus** and **Neptune**.

A pair of 7x50 binoculars trained carefully on the area 5° south of Beta (β) Capricorni will pick up the greenish, 3.8"-diameter disk of Uranus (magnitude 5.7). A little over 6° west of Uranus — bypassing the globular cluster M75 — your binocular view will take in Neptune's locale, which actually lies within Sagittarius' boundaries.

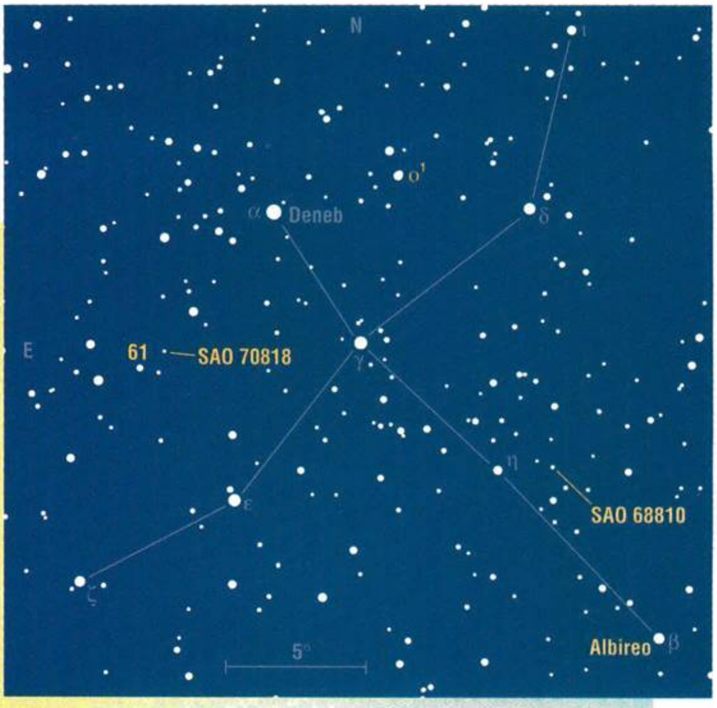
Here, though, you'll eventually want to use a small telescope and moderate magnification. What you see is not so much a disk but a 2.3"-diameter dot with a definite bluish tinge to it. Higher powers show this plainly.

Finally, **Saturn**, in Cetus, makes its first appearance around midnight as July opens, but by month's end rises during midevening. The planet reaches opposition on September 26.

Because we currently see Saturn lit slightly from the side, now is a good time to observe the globe's shadow cast across the rings passing behind the planet. All you need is a small telescope and moderate magnification.

About halfway up in the eastern sky after sunset are three bright stars that form the points of a large triangle. For untold years,

First Views:
Seeing Double in Cygnus



Nestled among the feathers of Cygnus the Swan are a few startlingly bright and beautiful double stars, anchored by that crown jewel of doubles, Albireo, Beta (β) Cygni. Binoculars or a low-power telescope will provide awesome views of these duos against the Milky Way's backdrop.

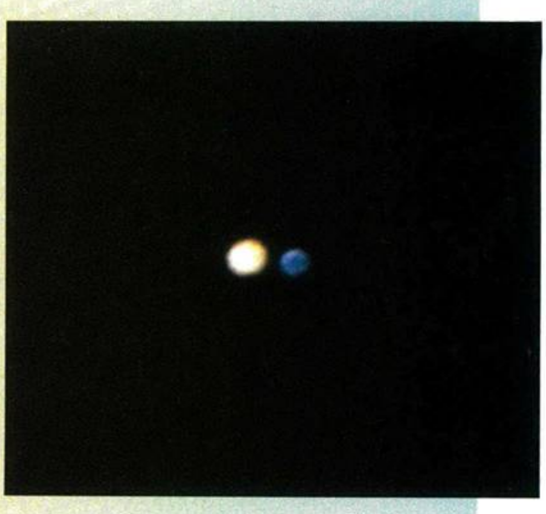
Let's start with Albireo, the crowning gem itself. It forms the eye of the Swan or, if you prefer, the foot of the Northern Cross, the other asterism for which Cygnus is famous. Albireo's primary star is a 3rd-magnitude light gold, offset by a 5th-magnitude aquamarine blue companion. Both are shown slightly defocused in the picture below to accentuate their colors. They lie 34" apart, delightfully wide for any low-power telescope and just separable in steadily held binoculars.

Far north of Albireo lies the triple star system Omicron^1 (o^1), or 31 Cygni, a few degrees to the west of Deneb. The 3.7-magnitude primary, a little less yellow than Albireo, is flanked by 5th- and 7th-magnitude blue companions, 5.6' and 1.8' away, respectively. The trio forms a "hockey stick" asterism when viewed through binoculars. Can you spot the companions' blue hues?

On the other side of Deneb and slightly to the south is 61 Cygni, a striking double in any instrument, with components shining at magnitude 5.3 and 5.9. This duo sports perhaps the best-matched pair of colored stars in the sky, both featuring fine orange hues and separated by 28", just a tad less than Albireo's separation. 61 Cyg is also noted for its very high proper motion across the sky. Backyard observers can track its change in position during a decade's time or so.

Only 1.2° northwest of 61 Cygni is an "Albireo wanna-be" called SAO 70818, discovered in the 19th century by William Herschel and located at 21h 02.3m, 39° 31' (2000.0). It has a 6.5-magnitude yellow primary with a 10.6-magnitude companion that radiates a striking blue, far deeper than Albireo's blue. With only 19" of space between them, this is a telescopic pair.

Herschel made another discovery 2° west of Eta (η) Cygni, the lower, central star in the cross. This second Albireo impersonator, SAO 68810, is a far fainter replica of Cygnus' crown jewel, but every bit as wonderful. The 6th- and 8th-magnitude pair are separated by 38"; look for them at 19h45.9m, 35°00' (2000.0). A late 19th-century double-star aficionado named William Henry Smyth imaginatively called this double's color "straw and smalt blue." *Smalt?* It wasn't in the two dictionaries I consulted. What superlatives would you use to describe its color? — *Alister Ling*


Michael Wake

the Summer Triangle, as it is called, has marked the opening of the summer observational season for amateur astronomers.

Highest in the sky around 9:30 p.m. local time is Vega, a pure white diamond whose name means "swooping eagle." Vega is not only the brightest star in the Triangle, it is also the fifth-brightest star in the sky (not counting the Sun, of course). Vega is the brightest member of the constellation Lyra the Lyre — the harp used by Orpheus in his attempt to charm Pluto and Persephone into allowing his wife out of Hades. The ploy didn't work, though.

Northeast of Vega is Deneb, marking the tail feathers of Cygnus the Swan. According to Greek myth, this great white bird was sacred to Venus. Cygnus is one of the more distinctive summer constellations. Some call it the Northern Cross; at around 9 p.m. Christmas Eve the cross stands erect above the western horizon just before setting.

Lying at the southernmost apex of the Summer Triangle is Altair, the leading light of Aquila the Eagle. Unlike the Swan, which is flying south, this celestial bird is winging its way northward. In nearly all ages, Aquila has been known as a bird of prey. The Arabic name for the constellation, al-Nasr al-Tair, means the flying vulture, and it is from this that we get the name of its brightest star.

By 2 a.m. at midmonth, the summer stars and the Milky Way are sliding off to the west. Coming on strong are the stars of autumn: The Great Square of Pegasus approaching the zenith; Andromeda following on its heels (or hooves); zig-zaggy Cassiopeia lying northeast of the square; Pisces and Aquarius to the south and east. Still farther south, just above the southeastern horizon, shines a lone star, magnitude-1.2 Fomalhaut, brightest luminary in Piscis Austrinus. Don't confuse it with Saturn, which is brighter and lies 37° to the northeast.

The winter constellations take to the stage in the eastern predawn sky around 4 a.m. The stars you see here are the ones

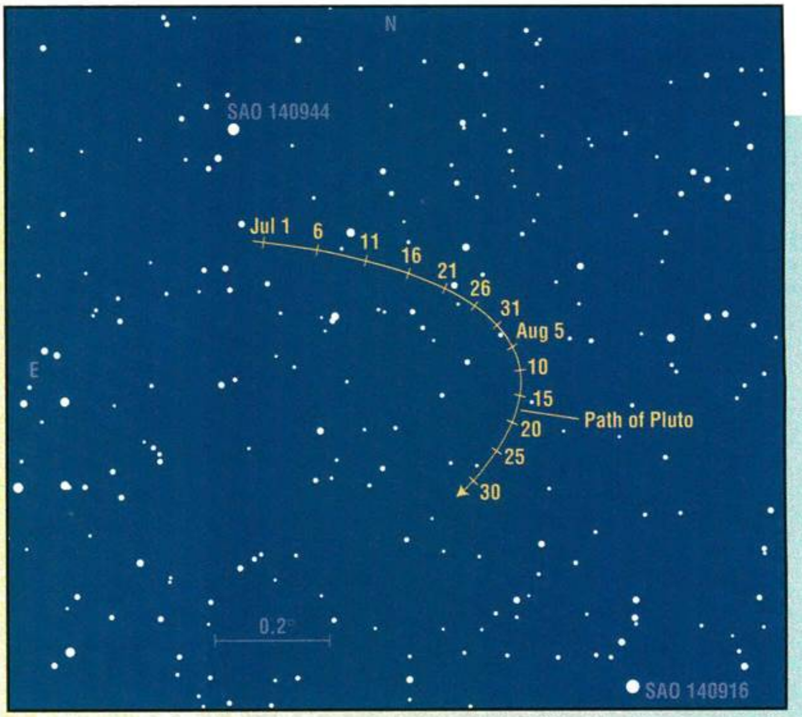
Observer's Challenge:
Dog Days of Pluto

Ninety-year-old Clyde Tombaugh often jokes that it took him a long time to discover Pluto because it "was so dog-gone hard to find." But if you're primed for the hunt, sniffing out this desolate, cold planet is not as tough as it sounds. It spends both this month and August lazily ambling in a loop through southwestern Ophiuchus. (Pluto's orbit is so inclined to the rest of the solar system it's not even in a zodiacal constellation.)

Pluto's easily tagged with an 8-inch scope if you have access to a dark site. Go for it during the first couple of weeks of July or August, when the Moon is out of the sky. You may also want to wait out the haze and humidity until a cold front sweeps more transparent air into your area.

First center a low-power field on Pluto's approximate area and then confirm the position of some brighter stars along the planet's path. Now increase the magnification to 200x or more. This darkens the eyepiece's field and brings still fainter stars into view. Since Pluto glows feebly at magnitude 13.7, patiently scrutinize all stars near the planet's predicted position. As you close in on this tiny planet, bear in mind it's only ⅔ the size of our Moon and lies 4 light-hours distant, compared to 1.3 light-seconds for the Moon.

If you don't spot icy Pluto right away, relax. Allow yourself to dark adapt and become familiar with the field. *Drape a dark cloth over your head while looking through the eyepiece.* Confirm your sighting by sketching the field and returning to it another night. The one faint star that has moved is Pluto. — *A. L.*

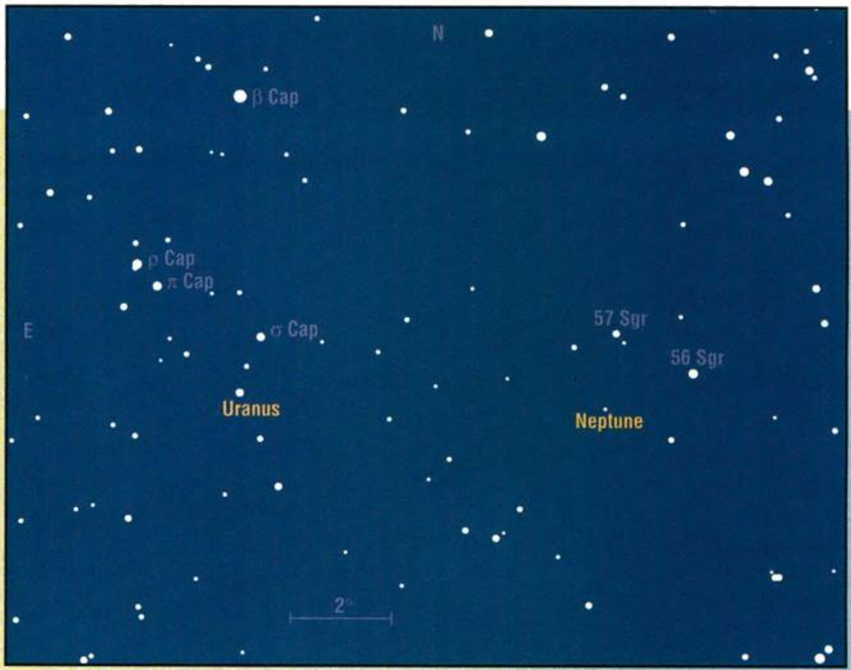


COORDINATES FOR PLUTO*

Date	R.A. (2000)	Dec.
July 1	16h05.5m	–7°17'
July 11	16h04.8m	–7°19'
July 21	16h04.3m	–7°22'
July 31	16h03.9m	–7°25'
August 10	16h03.8m	–7°30'
August 20	16h03.8m	–7°35'
August 30	16h04.1m	–7°41'

*Positions given for 11 p.m. EDT

Month of the Distant Giants



Uranus and Neptune are the distant cousins of Jupiter and Saturn, part of the solar system's gas giant family. These two huge balls of gas are easily followed in a small telescope or binoculars, especially this month. Neptune reaches opposition on July 18, followed a week later by Uranus on July 25. This means both giants are up all night, rising at sunset. Unlike Jupiter, any cloud variations are all but invisible with this pair; but check out their color.

Uranus is noticeably greenish in binoculars or a finderscope. The bigger the scope, the more prominent the green. This shade is an unusual glacial lake green — there's nothing else like it in the sky. On this color alone, you'll have no trouble following the nightly motion of Uranus on the finder chart. Start your search at double star Beta (β) Capricorni and drop south one binocular field.

At magnitude 5.7, Uranus is bright enough to see with the naked eye under dark, country skies. Few people have tried this relatively easy feat — it's a matter of desire and patience. Confirm your sighting by making a sketch of an adjacent starfield a week or two apart. The wandering star is Uranus shining across 2.6 light-hours of space. Unfortunately, Uranus' small 3.8" disk will challenge you to detect any detail at all through even the largest telescopes.

After Uranus, many observers mistakenly think Neptune is also a difficult target. Armed with a lowly pair of 7x50 binoculars, jump westward from Uranus a bit more than a binocular field, using 56 and 57 Sagittarii as guide posts. Consult the chart and make a sketch if you need to confirm the planet's position, marked by a "star" that glows a respectably bright magnitude 7.9.

Even at high power through a telescope, Neptune appears pale blue-green with a tiny 2.3"-diameter disk that is featureless even under excellent conditions. — *A.L.*

Jupiter's Midsummer Opposition

Mighty Jove rises at sunset in the east amid holiday fireworks. The planet seems aptly named for thunderbolt-wielding Zeus, since it reaches opposition on July 4, climbing at sunset to cross the south at midnight and set at sunrise.

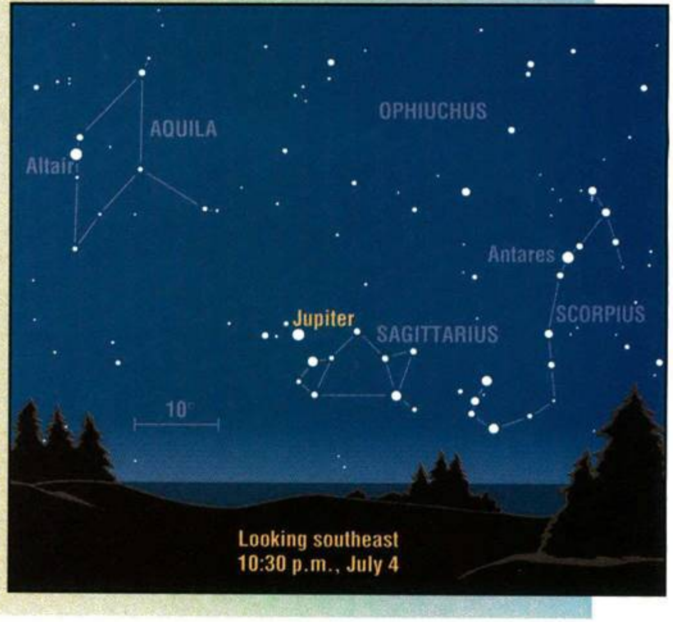
As you enjoy colorful fireworks with your neighbors, point out brilliant Jupiter and impress them with some mind-boggling facts, like its 390 million mile distance and mammoth diameter, some 11 times wider than Earth.

If Jupiter were moved to our Moon's distance, Earth would orbit deep inside the planet's deadly radiation belts.

In the coming days after the fireworks, invite people to view Jupiter through a telescope and marvel at its moons and cloud decks. Point out the centuries-old Great Red Spot, a storm that is three times wider than our home planet.

Feel like a shadow dance? Jupiter's moons cast their shadows on the disk every now and then, producing inky black dots.

If the seeing is poor, shadows may not be visible, but under good conditions they're quite a sight and easy to follow through even a 4-inch scope. Be patient — these features can be very subtle. — *A.L.*



Looking southeast
10:30 p.m., July 4

Comet Kopff Digs South

Periodic comets like this month's Comet Kopff are special. While they may not experience a swift rise to brilliance like Hyakutake, they do offer reliable performances with each return. Such is the case with Comet Kopff, which makes its way into the inner solar system every 6.4 years. For its pass this month, Earthbound observers are well placed.

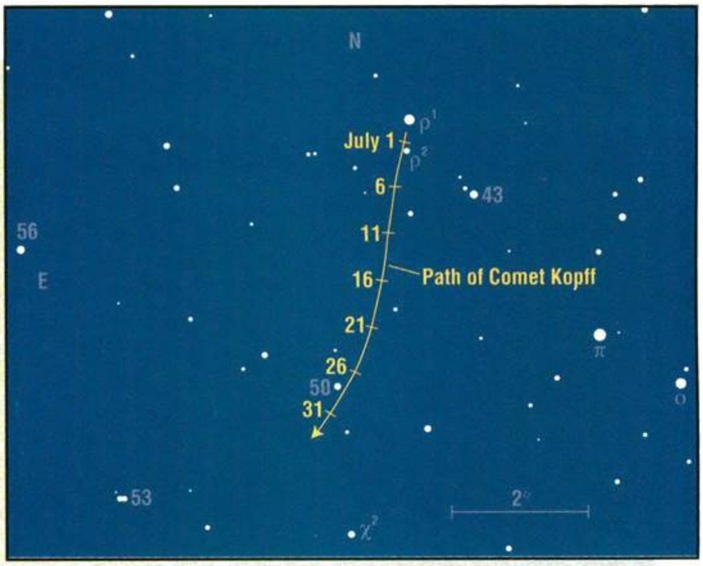
When you locate Jupiter in the evening sky (see "Jupiter's Midsummer Opposition," page 65), you're but a stone's throw from catching Kopff. The comet starts July at the top of Sagittarius' Teaspoon, beneath Rho¹ (ρ¹) Sagittarii.

As the month unfolds, Kopff digs southeastward along the Teaspoon's 4° length. This means the comet's only two binocular fields away from Jupiter at any given time during the month and easy to track. All this time it should brighten past 9th magnitude, allowing binocular observers to follow its progress. Look for a fuzzball that gets brighter toward its center.

Scope users should also use July to look for changes in the shape and direction of Kopff's coma and tail. Near New Moon at midmonth, the tail rotates behind the head, and by month's end it stretches out east.

Remember that Full Moon falls close to the 1st and the 30th; Kopff's tail will be more difficult to see a week either side of those dates.

Meanwhile, just 15° away to the north and west, Comet Hale-Bopp cruises the rich Milky Way starfields of Scutum (see "Showtime for Hale-Bopp," page 68). How many other new comets will become visible this summer? Only time will tell. — *A.L.*



COORDINATES FOR COMET KOPFF*

Date	R.A. (2000)	Dec.
July 1	19h22.0m	–18°11'
July 6	19h22.6m	–18°50'
July 11	19h23.0m	–19°31'
July 16	19h23.5m	–20°13'
July 21	19h24.2m	–20°54'
July 26	19h25.2m	–21°34'
July 31	19h26.8m	–22°11'

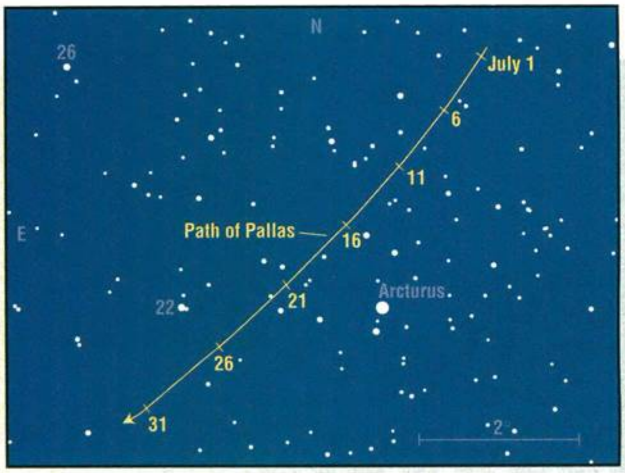
*Positions given for 11 p.m. EDT

Pallas Arcs Past Arcturus

Asteroid 2 Pallas is a snap to follow in a telescope this month. It spends all of July arcing just north of brilliant magnitude-0.0 Arcturus, the northern sky's brightest star. On the evenings of July 16 through 19, the 9.6-magnitude asteroid lies only 1° northeast of ruddy Arcturus in Bootes.

To find the 330-mile-diameter spheroid, use the chart to hop from fiery orange Arcturus. As Earth pulls ahead of Pallas during July in a faster orbit that's closer to the Sun, the asteroid drops from magnitude 9.4 to 9.8, near the limit for most binocular users.

Because there are few stars in this area of sky, you should have little trouble pinpointing Pallas in a 3-inch or bigger scope. On the evening of July 19, Pallas approaches to within an arcminute of a 9.8-magnitude star, and does a repeat performance with an 8.9-magnitude star on July 23. Observations taken 15 to 30 minutes apart should reveal the asteroid's noticeable motion.



Pallas often journeys far from the beaten planetary path. Most asteroids have orbits much closer to the plane of the solar system, but Pallas' orbit is inclined a whopping 35°. This is why it appears closer to Arcturus, more than 30° above the line of the ecliptic. Wayward Pallas was the second asteroid discovered, first glimpsed by Heinrich Olbers on March 28, 1802. — *A.L.*

you will see in the eastern evening sky come autumn.

Giraffe-shaped Perseus is highest, trailing Cassiopeia. Capella blinks wildly in the thick of the morning atmosphere to the northeast. Its home constellation, Auriga the Charioteer, becomes more distinct the higher it rises above the murk. To the right (south), your eye may catch on a misty nexus of stars, about 30° above the eastern horizon. This is the Pleiades, also called the Seven Sisters. If your binoculars are still handy, you'll definitely want to scan this tiny, dipper-shaped star cluster.

Below the Pleiades, the V-shaped Hyades cluster mounts into the sky; the face of the constellation Taurus the Bull. At the end of the easternmost leg of the V is reddish Aldebaran, brightest star in Taurus.

Also in the vicinity, and even nearer the eastern horizon, are the planets **Venus** and **Mars**. Venus is the brighter of the two, reaching greatest brilliancy this month (magnitude –4.5) on the morning of the 17th. Mars is much fainter at magnitude 1.5.

You will want to go out and view this area of sky on the morning of July 12. Brilliant Venus will lie a little more than a degree to the southwest of the waning crescent Moon. The planet will be positioned off the top horn of the crescent on the dark side. With Aldebaran, Mars, and the Pleiades all in the vicinity, this should make a splendid composition for astrophotographers. □

Jeff Kanipe is managing editor of ASTRONOMY *magazine. Alister Ling works as a meteorologist for Environment Canada.*

Gazetteer to Noctilucent Clouds

Oscar Van Dongen

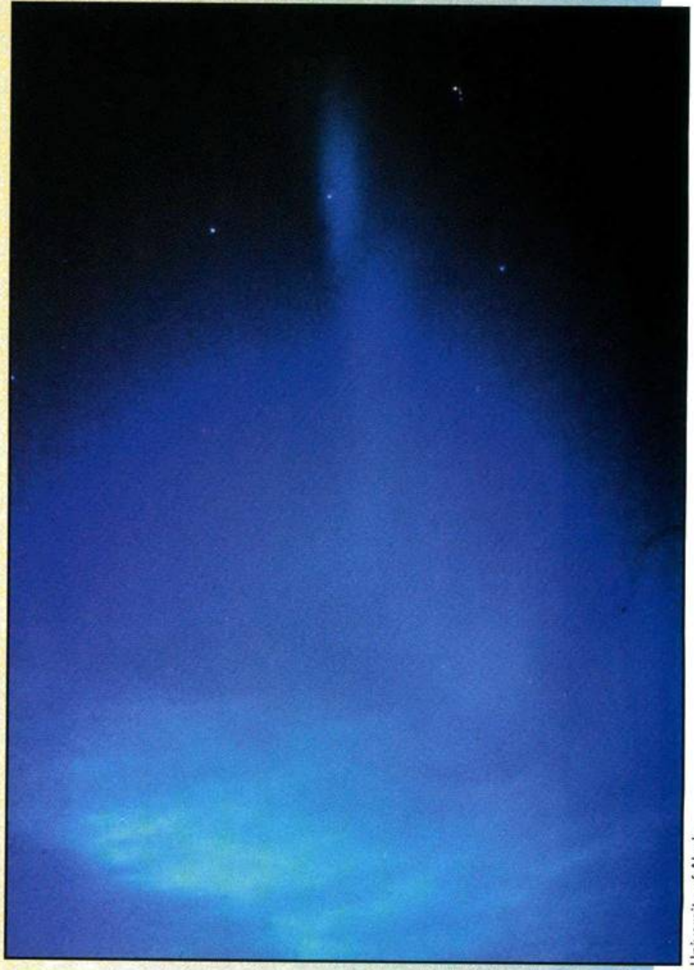
The name "noctilucent cloud" conjures up images of ghostly midsummer sprites and spirits. Noctilucent clouds (NLC), however, are just icy clouds that range at extremely high altitudes, up to 50 miles, compared to regular clouds that can reach no higher than 11 miles. NLCs form when water vapor from thunderstorm tops slowly diffuses upward and condenses out on tiny specks of meteor dust.

But the delicate NLC are for northern eyes only. The farthest south they have ever been observed is latitude 46°, which means anyone living north of a line that connects northern Maine through the upper peninsula of Michigan to Washington State can see the ethereal clouds. Northern Europeans also have front-row seats.

NLCs typically linger in the same area of sky as aurorae, hugging the northern horizon except for rare, impressive half-sky extravaganzas. NLCs are also only visible during the short summer nights of northern latitudes, when the summer Sun just manages to dip below the northern horizon enough to provide darkness, yet keep the clouds' lofty vantage point in sunlight.

A bright display of NLCs is one of nature's wonders — quasi-luminous, bluish-white horizontal streaks gradually change into ripples, waves, and most beautiful of all, whorls. At first glance they look like high, wispy cirrus clouds, of the mare's tail variety. But on further observation they sport a special sheen of iridescent bluish white — unlike cirrus clouds, which are decidedly reddish at sunset and grey a few minutes later. The much lower cirrus clouds also appear black against the glowing backdrop.

Look for NLCs to change their appearance in a matter of minutes. As the Sun moves along below the northern horizon, different parts of the sheet light up, producing the illusion of gradual movement. Binoculars provide an easy way to absorb the visual feast. — *A. L.*



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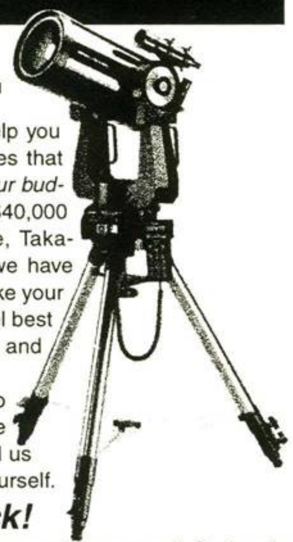

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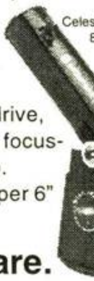

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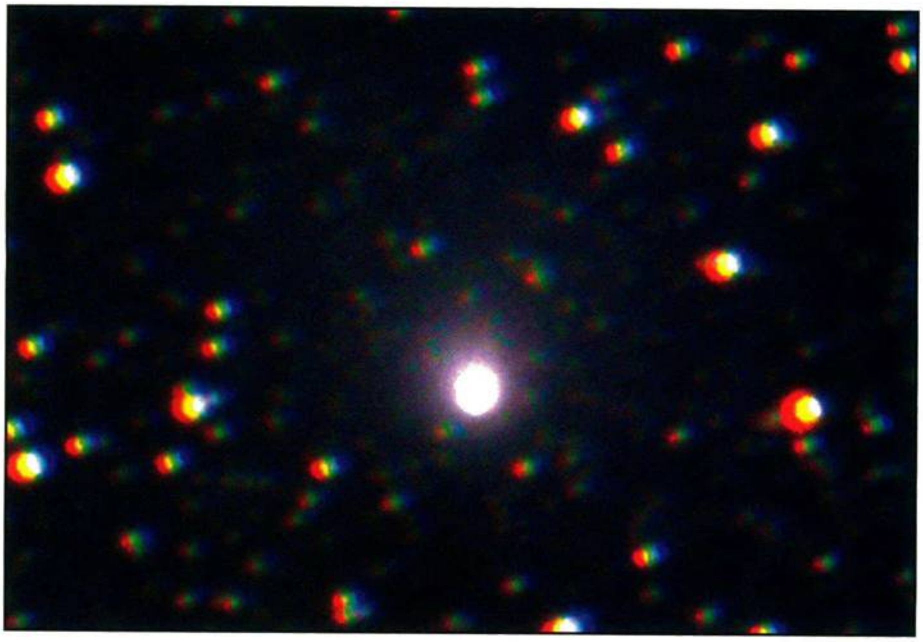
Showtime for Hale-Bopp

The great comet of 1997 reaches naked-eye brightness as it traverses the bright glow of the summer Milky Way.

by David J. Eicher



Beatrice Mueller, NOAO

A GLEAM IN THE TELESCOPE, Comet Hale-Bopp glows dimly as photographed with the 0.9-m telescope at Kitt Peak, Arizona, on August 13, 1995.

The waiting is over. It's showtime. A year after its discovery by two American backyard astronomers, Comet Hale-Bopp is approaching naked-eye visibility. No longer is it a fuzzball inching its way northwestward through Sagittarius. Soon to be visible as a hazy spike of light under a very dark sky and quite cometlike in binoculars, the comet is just beginning its rise to what may surpass Comet Hyakutake this spring and perhaps even vanquish Comet West in 1976.

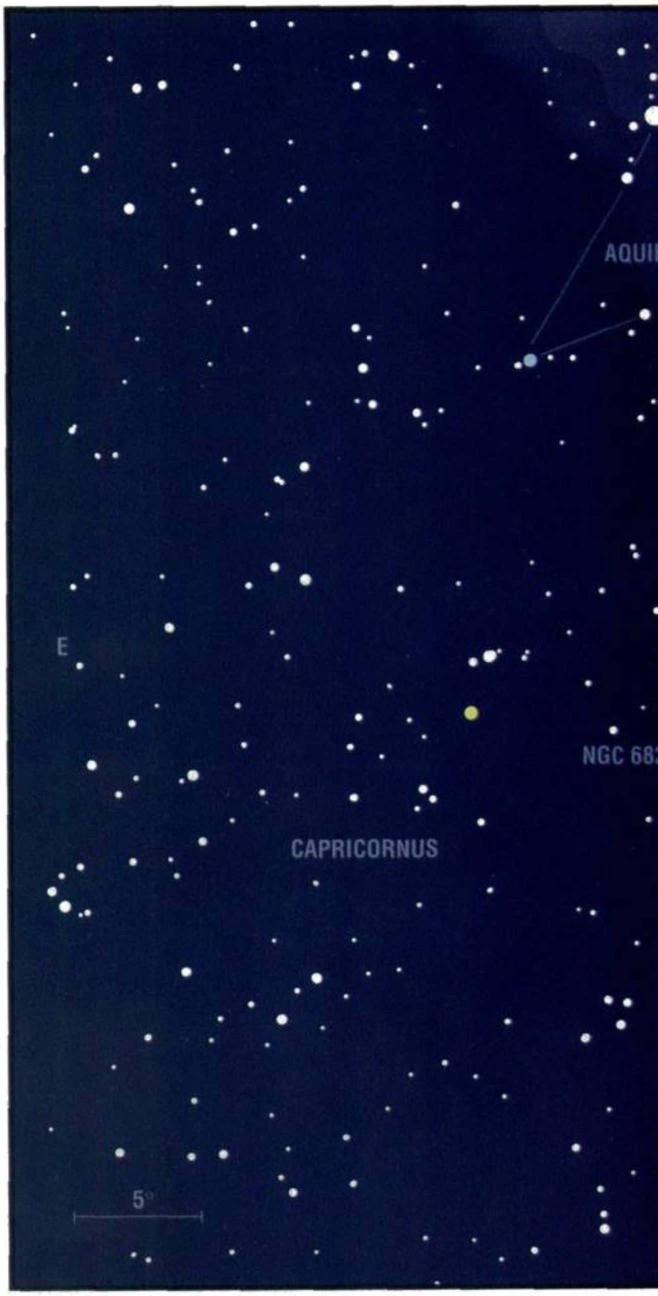
WHERE TO FIND COMET HALE-BOPP

Date	R.A. (2000)	Dec.	Mag.	Constellation
June 1	19h28.6m	–14°44'	7.0	Sagittarius
June 15	19h14.9m	–13°26'	6.6	Sagittarius
July 1	18h54.7m	–11°53'	6.3	Scutum
July 15	18h34.7m	–10°29'	6.0	Scutum
Aug. 1	18h10.7m	–8°52'	5.7	Serpens Cauda
Aug. 15	17h53.7m	–7°42'	5.5	Ophiuchus
Sept. 1	17h38.9m	–6°32'	5.4	Ophiuchus

Along with the date, this table provides the comet's position in **right ascension** and **declination** (epoch 2000.0), equivalent to longitude and latitude on the sky. The **magnitude** is a measure of the comet's brightness: the faintest stars visible to the naked eye glow at about magnitude 6, the brightest at about magnitude –1.5. The **constellation** column shows which bright star group the comet appears to be residing in.

ORBITAL ELEMENTS FOR HALE-BOPP

Perihelion Time (*T*)	1997 April 1.64155
Perihelion Distance (*q*)	0.9130230 AU
Eccentricity (*e*)	0.9944413
Argument of Perihelion (ω)	130.66776°
Longitude of ascending node (Ω)	282.47292°
Inclination (*i*)	89.41422°

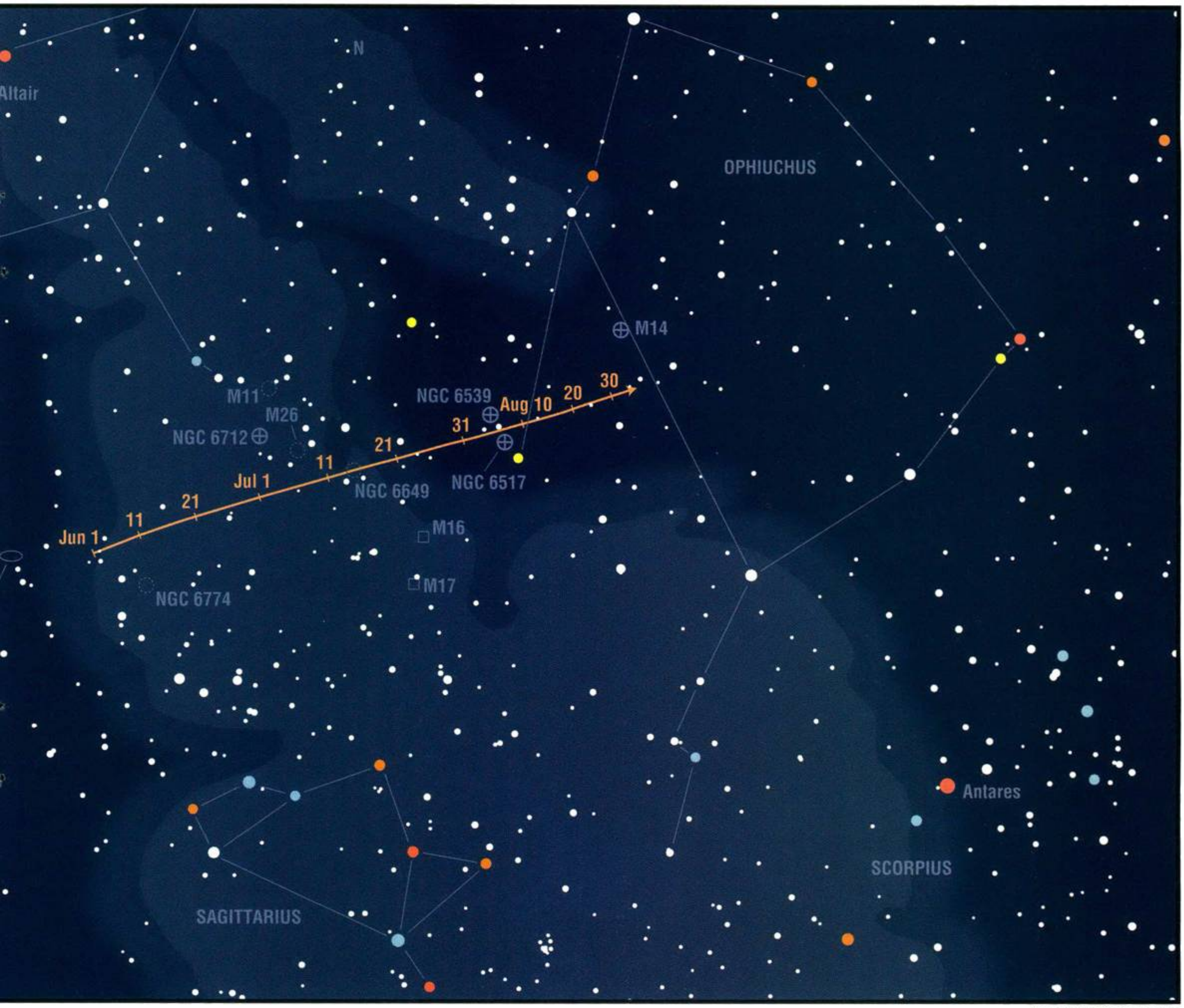


Map Info

(For an overview of the comet's entire apparition, see "Here Comes Hale-Bopp," February 1996.)

Hale-Bopp's rise to naked-eye brightness spans the period June 1 to September 1, as it graces the evening sky and moves from Sagittarius into Scutum, Serpens Cauda, and on into the wide expanse of Ophiuchus. (Exactly when various observers begin to see the comet's glow with eyes alone depends on sky darkness and observing experience, among other factors.) During this period the comet should brighten gradually from magnitude 7.0 to 5.4, probably grows a slender tail that may stretch a degree or two long, and slides across the brightest part of the Milky Way star clouds in the summer sky. It will be well-placed for evening observing, interrupted occasionally by bouts of bright moonlight, and approaching an abrupt turn northeastward in October. The September issue of Astronomy will pick up the coverage as the comet continues to brighten through the autumn months.

For now, however, how Hale-Bopp will perform this summer remains open to question. Exactly how bright the comet will appear and the size of any tail it will grow are as yet mysteries. In early June the comet glows with the light of a 7th-magnitude star and lacks a significant tail. Hale-Bopp has been undergoing periodic variations in brightness, suggesting it will not fade into oblivion in the near-term. It has not as yet cracked apart, a phenomenon that occurs to many comets as they approach perihelion, their closest point to the Sun. And Hale-Bopp has not yet developed a significant



ASTRONOMY: Elisabeth Rowan

dust tail, another potential indicator of great brightness. Most of the bright naked-eye comets of the past century had bright dust tails, including West.

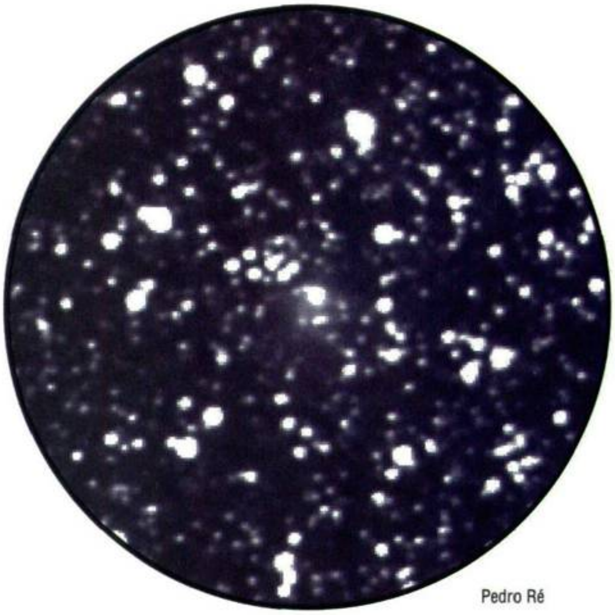
The comet's sheer physical size is not known, as the nucleus — anywhere from a few miles to more than 20 miles across — is obscured by a thick cloak of gas and dust forming the coma. Astronomers have detected active jets of dust and gas emanating from the comet's nucleus, most prominently in September and October 1995. Before the comet's performance becomes clear, we'll need to watch it ramp up in brightness through the summer.

During June Hale-Bopp glides slowly northwest through Sagittarius, beginning from a spot about 4° west of the elusive Barnard's Galaxy (NGC 6822), a member of the Local Group of galaxies. To find it, aim your finder scope at the 5th-magnitude star Upsilon (υ) Sagittarii and move 2° northeast. Be sure not to confuse it with the sparkly glow of the open cluster NGC 6774, 1° west of Upsilon Sgr.

The best times for observing Hale-Bopp in June come from about the end of the first week through the beginning of the last week. This time affords a relatively moonless window of evening sky, with the Last Quarter phase coming on June 8, New Moon on June 15, and First Quarter on June 24. Once you find the comet, tracking it will be easy because it moves so slowly. By June 15, Hale-Bopp lies 4° northwest of Upsilon Sgr and glows at magnitude 6.6.

July affords still better opportunities for watching Hale-Bopp as the comet brightens

SPROUTING A DEMURE TAIL, Comet Hale-Bopp appears like a fuzzy blob in a rich star field on September 21, 1995.


Pedro Ré

further and moves into the thick of the Milky Way. The best window during the month extends from late in the first week through the beginning of the third week, as Last Quarter Moon arrives on July 7, New Moon on July 15, and First Quarter on July 23. During this period the comet dances between the rich area of Milky Way marked by the Eagle (M16) and Omega (M17) nebulae and the bright glow of the Scutum star cloud, which contains many little deep-sky treasures. On July 1 Hale-Bopp shines at magnitude 6.3, may well have developed a short tail, and hangs less than 3° south of the bright globular cluster NGC 6712. It is also 3° southeast of the open cluster M26, and 5° south of the Wild Duck Cluster (M11).

Thus begins a grand opportunity for wide-field astrophotographers to capture Hale-Bopp with other, more distant night sky wonders. On July 15, glowing at 6th magnitude, the comet lies 2° south-southwest of Alpha (α) Scuti and less than 1° north of the open cluster NGC 6649. Hale-Bopp now straddles the brightest part of the Scutum star cloud and is surrounded by the mist of countless suns.

By August the comet's increasing brightness will begin to show as casual comet watchers start to take it seriously. During this period Hale-Bopp moves from Serpens Cauda into Ophiuchus, away from the glistening Milky Way. It brightens from magnitude 5.7 on the first to 5.4 by month's end, and probably sports a neat little tail (a bluish gas tail and — hopefully — that indication of bright things to come, a dust tail). The best window for spotting the comet ranges from the first days of the month to about August 20, when the Moon returns to the evening sky. On August 5 the comet slides between the globular clusters NGC 6517 and NGC 6539, separated by a mere 2°, and briefly swishes past the 6th-magnitude double star Tau (τ) Ophiuchi. It finishes the month some 3° south of the bright globular M14.

By September 1 astronomers across the world will have a pretty good handle on what they do not now know: How bright and active Hale-Bopp will appear during its peak brightness in the spring of 1997. This summer, which marks the comet's rise to naked-eye visibility, will tell us if we have a second great comet in two years. □

A BRIGHT ICEBALL this winter and spring, the comet hinted at its outstanding performance to come. This image was taken February 26, 1996.

Tim Puckett

Dave Eicher is associate editor of this magazine. He occasionally observes comets, mostly because they look pretty much like faint galaxies.

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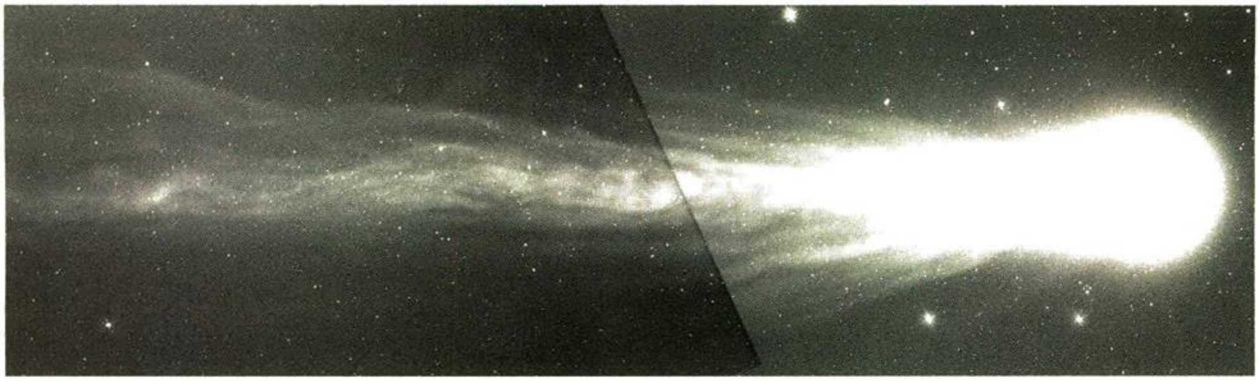

Chris Schur

Hyakutake's Spring Surprise

Last February, experts were guardedly optimistic that newly discovered Comet Hyakutake would end a 20-year drought of spectacular comets. They certainly didn't expect such a whirlwind performance.

by John Shibley and Robert Naeye

Sometimes the best things in life are unexpected.

Unexpected indeed! If any amateur astronomer (or a professional one, for that matter) had predicted a year ago that a comet found lingering in the hinterlands of predawn Libra would grow to cover whole tracts of sky within two months of its discovery, essentially never setting during two weeks in March for observers in the Northern Hemisphere, they probably would've been greeted by more than a fair dose of healthy skepticism.

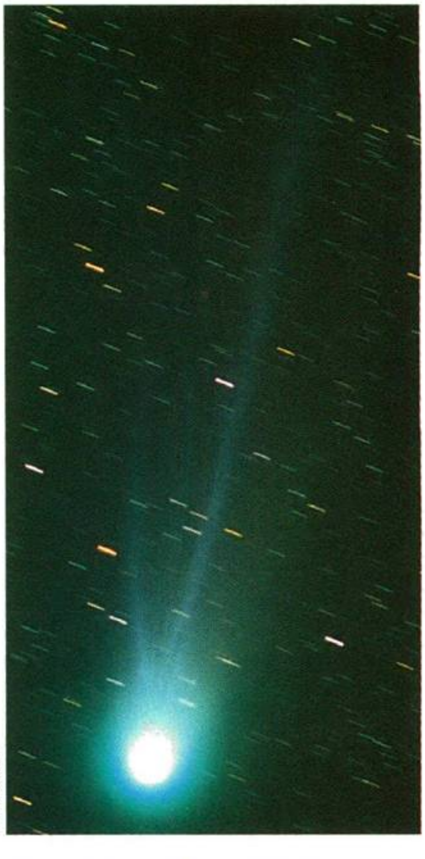
And they would've deserved it. Who in their right mind can ever predict such a wonderful comet as Hyakutake? Perhaps you still don't believe it happened — maybe the comet was a wonderful vision that came and went. But shut your eyes, recall what you saw, and then thumb through the next half dozen pages to see what fellow sky enthusiasts, both amateur and professional, shared with ASTRONOMY. Hyakutake, the Great Comet of 1996, provided proof that like a dream come true, the best things in life are truly unexpected.

Close Enough to Touch

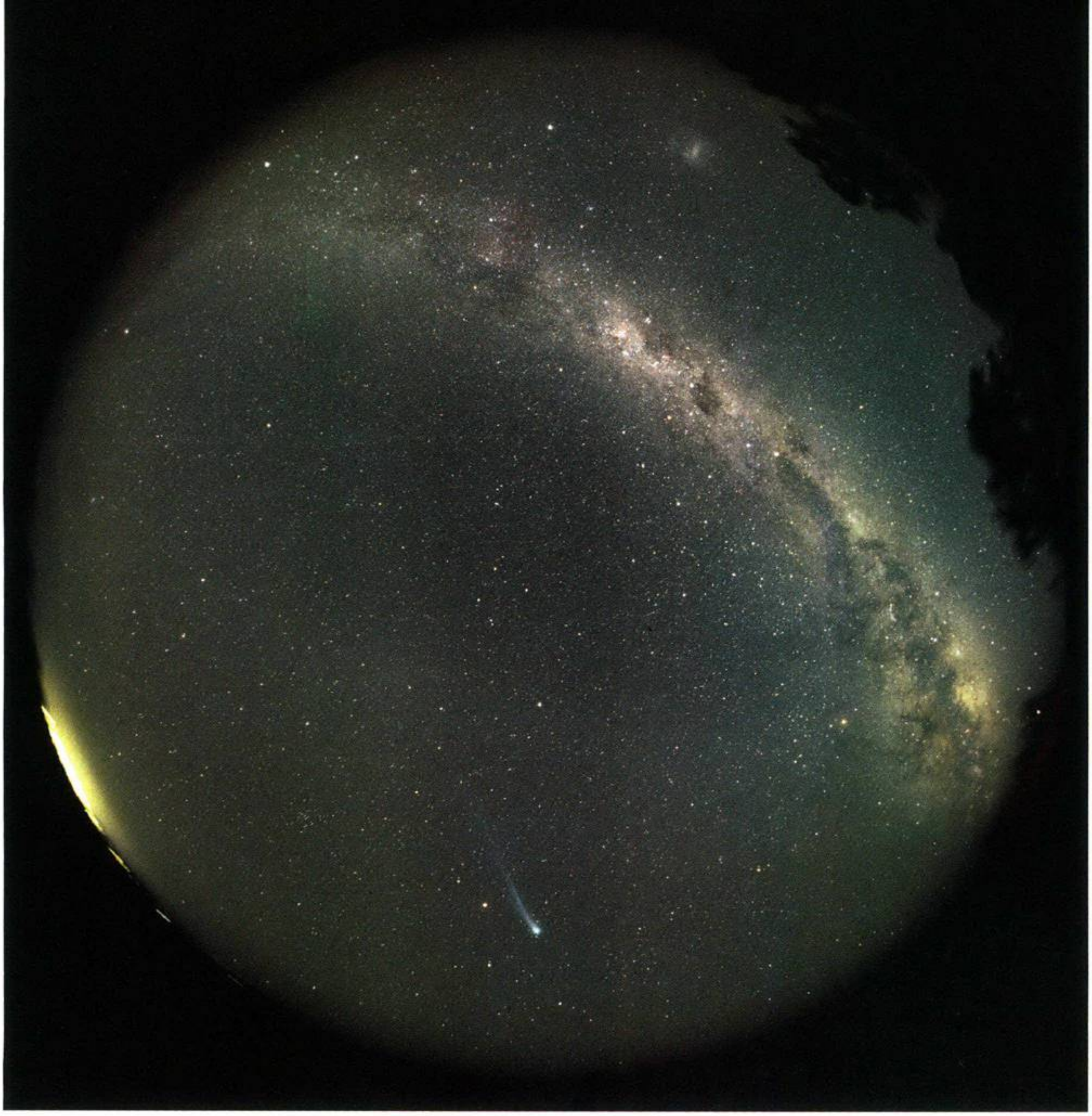
Intrinsically, Comet Hyakutake, also designated P/1996B_2, was just a run-of-the-mill comet. If it had come in from the other side of the solar system, or if Earth had been in a different part of its orbit, 1996B_2 would have looked like any one of a half dozen telescopic comets visible at any time of the year.

But Hyakutake was different. This dirty snowball practically aimed its run for the inner solar system right at Earth. We had front-row seats to the unfolding drama, a reawakening Hyakutake hadn't undergone for 8,000 years. From south of the ecliptic, the plane of the solar system, Hyakutake whistled past Earth on March 25 at 150,000 kilometers per hour, picking up 1,500 kph each day as it fell deeper into the Sun's gravitational embrace. Each passing day also put it closer to the solar warmth, which sublimated a veneer of dirty ice to create a rarefied tail of molecules and atoms stripped of electrons by solar radiation and pushed into a tail by the Sun's magnetic field. The photos here attest to this; Hyakutake's tail blew straight back from Sol like a windsock carried by summer breezes.

Tail colors, some of which were spotted with the naked eye, included eerie blue tones of CO^+ and, if you look carefully at some of these pictures, the blood-red signature of H_20^+. Other qualities, like overall apparent size and brightness, made this comet


Tom Stafford

SHAKING OFF AN 8,000-YEAR SLUMBER, Comet Hyakutake sports a tail tens of millions of kilometers long. The tail's sinuous nature (top of page) and predominantly blue, spiky tail (above) betray its gaseous essence in these pictures taken on March 21 and 22, respectively. A dustier tail came later, when things really heated up.



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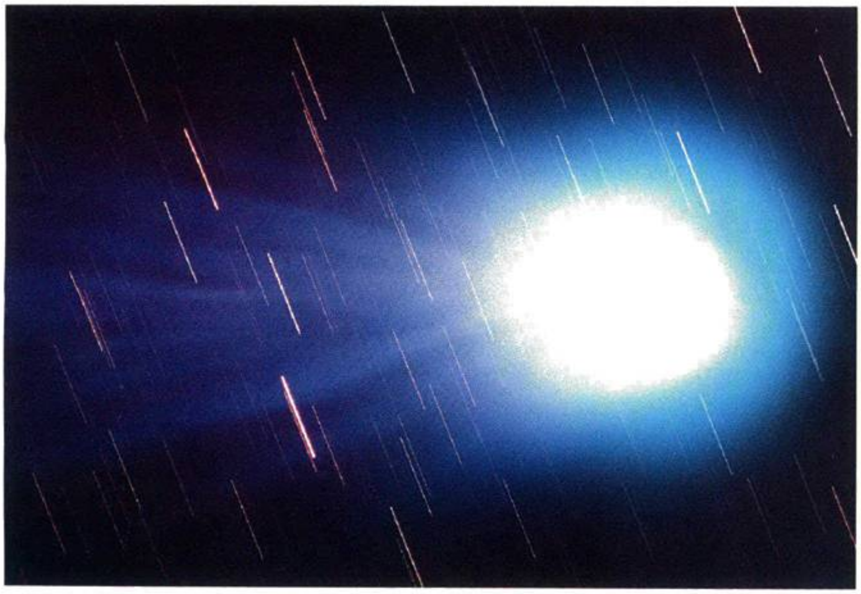


Jason Ware

HYAKUTAKE CLEAVES the Australian sky in this photo (above) snapped when it was midmorning on March 22 for North Americans. Nearby is orangish Arcturus; farther to the left is the star cluster Coma Berenices. Two bands cross this picture: the bright Milky Way and, running from nine to four o'clock, faint zodiacal light. The comet's long tail ends at the Gegenschein, the Sun's oblong reflection off of interplanetary dust. On the Milky Way's far side, note the Large Magellanic Cloud at one o'clock. The close-up picture (left) was taken about eight hours earlier. At this photo's scale, Hyakutake's 1- to 3-km-diameter nucleus is just a pinpoint lost in an overexposed coma.

exceptional. With a 144,000-km-wide coma and 144-million-km-tail, Comet Hyakutake was typical of many comets. What made it unusual for humanity during March, though, was its 15.2 million kilometer closest approach to Earth on the morning of March 25. Such a close pass not only made the comet look bright (estimates range up to magnitude –0.8), but humongous as well.

Flyby week saw Hyakutake sport a coma that covered 2° of sky, an equivalent diameter of four full Moons. And as if that wasn't spectacular enough, by some estimates Hyakutake's tail stretched across 110° of sky. (For what it's worth, that's 220 full Moons.)

This close pass also provided observers armed with even the smallest of scopes unprecedented views of activity near the comet's tiny nucleus, which spewed gas and dust at an astonishing rate of several tons a second. Spikes of ionized gas gleamed like searchlight beams along the axis of the comet's long tail. A mushroom-shaped head plowed like a battering ram into the Sun's constant stream of charged particles. As the nucleus warmed, whole pieces of the comet's surface sloughed off, sublimated, and ionized to create bead-like features that sprouted mini-tails of their own.

As Hyakutake raced past Earth, an ever more active surface baking in the increasing solar heat belched out greater amounts of dust. This lent a yellowish (reflected sunlight), granular appearance to the inner coma. Into April, as the May 1 perihelion passage approached, more and more observers reported evidence of a dusky dust tail.

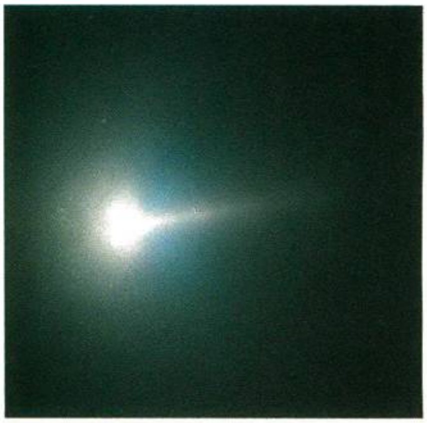
All This and Science Too!

But as if the in-your-face aesthetics of a comet's close approach weren't enough to enjoy, working astronomers, in their endless quest for understanding, turned every available instrument on Hyakutake to break new ground in the study of comets. The pros had their surprises also.

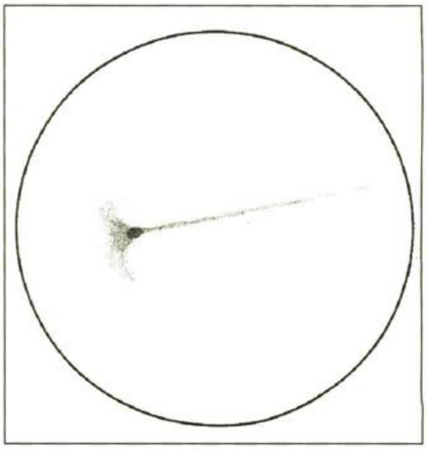
Perhaps the most surprising early scientific discovery was the detection of significant X-ray emission from the comet. Only extremely violent and energetic processes produce X rays, so scientists thought a cold, inert object such as a comet would be virtually silent in the X-ray domain. However on March 27, the German X-ray satellite Rosat detected a strong X-ray signal coming from a crescent-shaped region just in front of the comet. The emission varied in intensity over the course of just a few hours.

X rays had never before been detected from a comet, leading Michael Mumma of NASA's Goddard Space Flight Center to comment, "We had no clear expectation that comets shine in X rays. Now we have our work cut out for us in explaining these data, but that's the kind of problem you love to have."

Mumma and his colleagues tentatively put forth two possible explanations. First, perhaps X rays from the Sun were absorbed by a



Tom Martinez

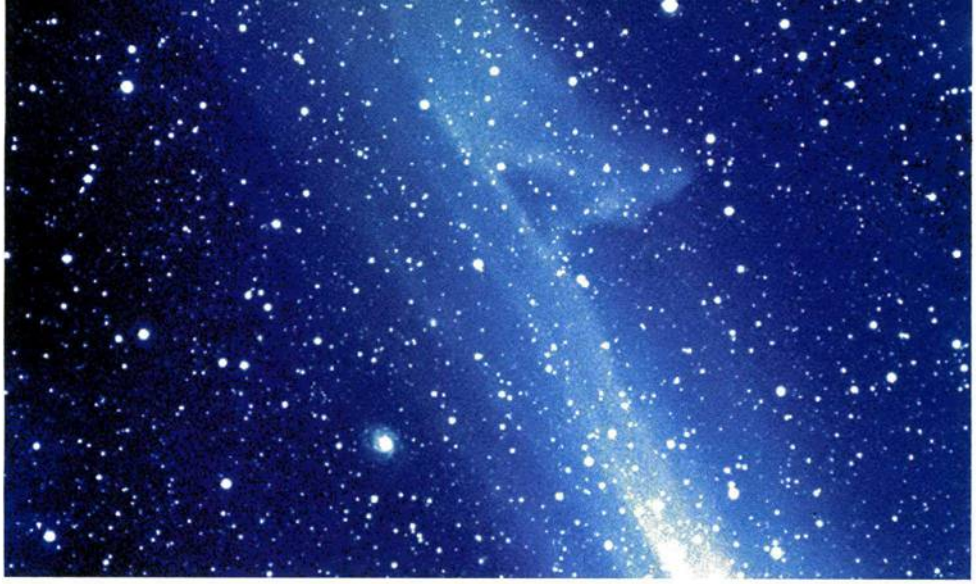


Tom Johnston

OUR SUN'S HEAVY HAND works on the comet's delicate environment (above). Gas and dust percolate off the nucleus' Sun-facing side to form a bow shock in the onrush of solar wind, and then gets driven back into a pencil-thin inner tail.

UNABLE TO RESIST the Sun's onslaught of heat, Comet Hyakutake gave up a morsel of itself on March 24. The French observatory Pic du Midi captured a clump of comet mantle separating in two black-and-white photos taken four hours apart. Note in the left picture how the debris cloud shows up as a brightening where the inner tail joins Hyakutake's bright, inner coma. Several hours later the blob pinches off in earnest to begin a multi-million-kilometer drift up the tail. Twenty hours later, the Hubble Space Telescope imaged the comet's inner coma and the chunk after it had moved several thousand kilometers away from the nucleus (orange pictures). Each HST frame is 760 km wide.

Pic du Midi



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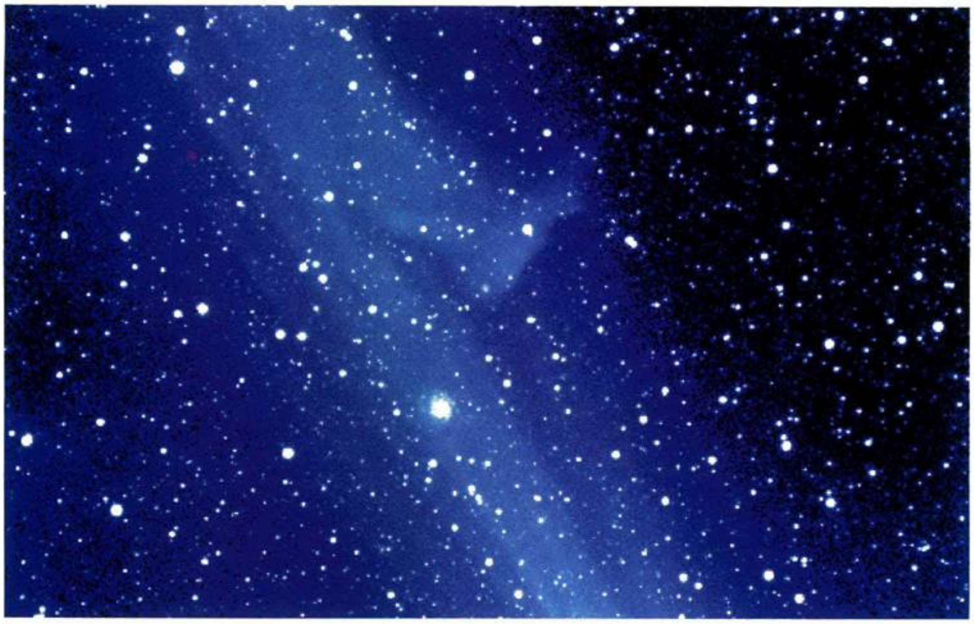
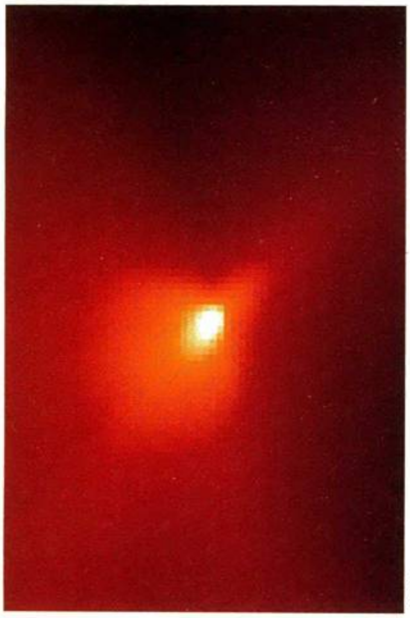


J. DeBuizer, J. Radowski/Univ. of Florida

A COMET'S WISPY tail reveals the ever-changing solar wind. Here, a change in the solar wind's magnetic polarity caused a "disconnection event" that worked along Hyakutake's plasma tail on the morning of March 25. Also on that morning, one of the sky's largest spiral galaxies lent itself as a scale to Hyakutake's awesome size. Just below and left of center is M101, a face-on spiral galaxy in Ursa Major some ⅔ the apparent diameter of the Moon. The tail's motion across the galaxy is in just under two hours' time.

Pic du Midi



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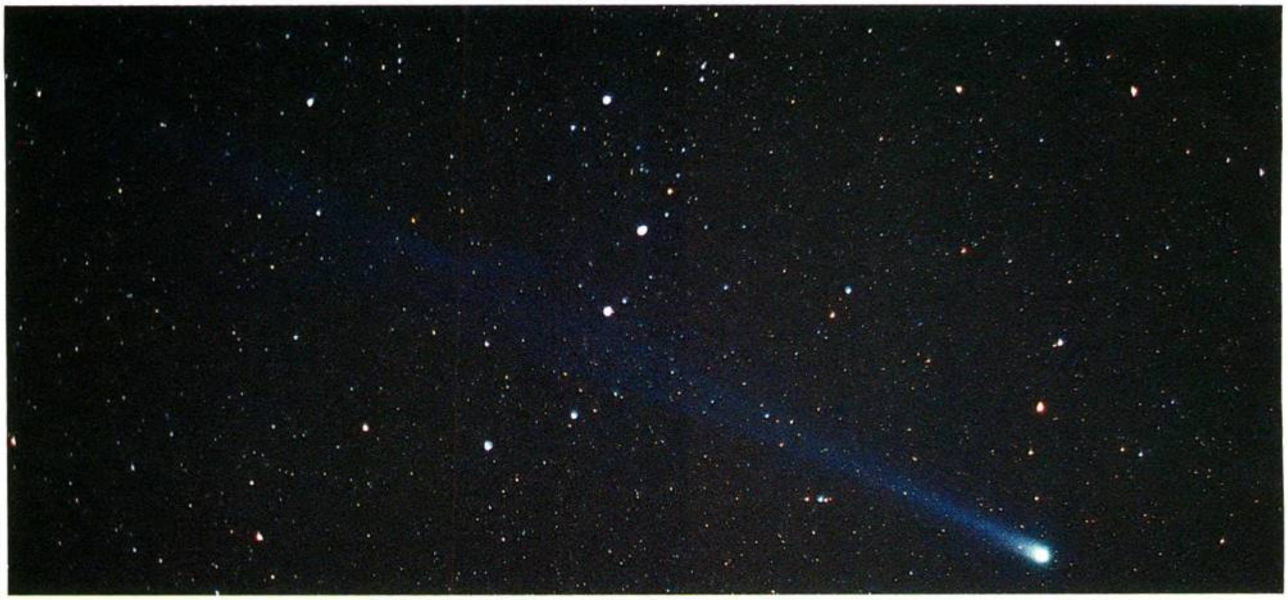
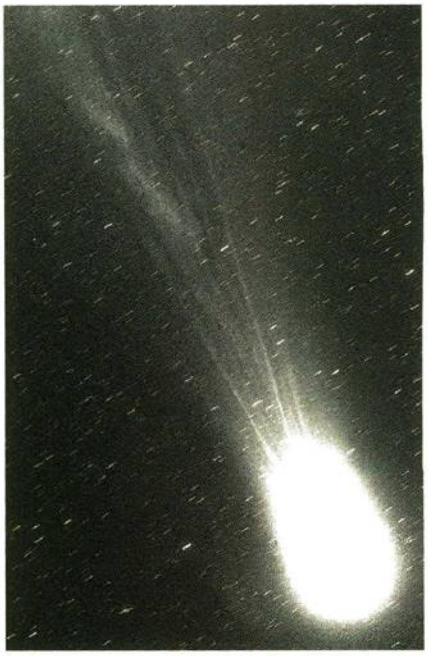
STScI



Jerry Schad



Gerald Rhemann

A COMET-LOVER'S DREAM come true, Hyakutake had something for everybody. It was big: Only a 24mm wide-angle lens could capture its 55-plus degree tail on March 25 from Ursa Minor, through the Big Dipper, and into Coma Berenices (above). It was rich: Close-up photos harbored a wealth of detail, as in the Schmidt camera photo taken on March 23 (near right). Note how fibrous inner ion tails warp in the solar wind as they project farther from the nucleus. It was close: Some astroimagers incorporated Hyakutake's vastness into terrestrial scenes (opposite, top). It was speedy: Astrophotographers had to hone their tracking skills to keep up with Hyakutake's fast motion (opposite, bottom). Guiding on the starlike nucleus captured delicate detail visible even in binoculars.

cloud of water vapor surrounding the nucleus and then re-emitted by the water molecules. Alternatively, maybe the violent collision between gaseous particles in the coma and the solar wind generates the X rays.

On March 25, when the comet was about 15 million km from Earth (1⁄10 the Earth-Sun distance), a team led by Harold Weaver of the Applied Research Corporation pointed the Hubble Space Telescope toward Comet Hyakutake. The telescope's Wide Field and Planetary Camera 2 scrutinized a region surrounding the nucleus, providing a detailed look at the heart of the comet.

While dust obscured the actual nucleus, the Hubble images showed that most of the dust was being ejected from the comet's Sun-facing side. The Hubble images revealed three small chunks that had apparently broken off the comet, each forming its own little tail. Hubble also spotted highly energetic jets of gas and dust streaming off the nucleus.

Because dust particles obscure the nucleus, astronomers had to rely on other techniques to measure its size. On March 24 and 25, Steve Ostro of the Jet Propulsion Laboratory and his colleagues bounced radio waves off the nucleus using the 70-meter antenna at Goldstone, California. The echo pattern revealed a nucleus only 1 to 3 km across, a far cry from Comet Halley's 15- by- 8-km nucleus, and Comet Hale-Bopp's apparent 40-km-wide nucleus.

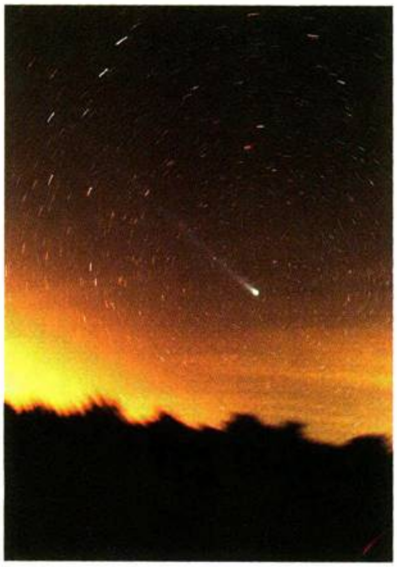
Ostro's radio observations also detected particles zooming away from the nucleus at speeds of at least 10 meters per second (22 mph). The radio studies revealed that the coma must contain a huge swarm of particles not much smaller than a centimeter across. The radio echo from these particles was about 10 times stronger than the echo from the nucleus itself.

Observations from Observatoire de Pic du Midi in France

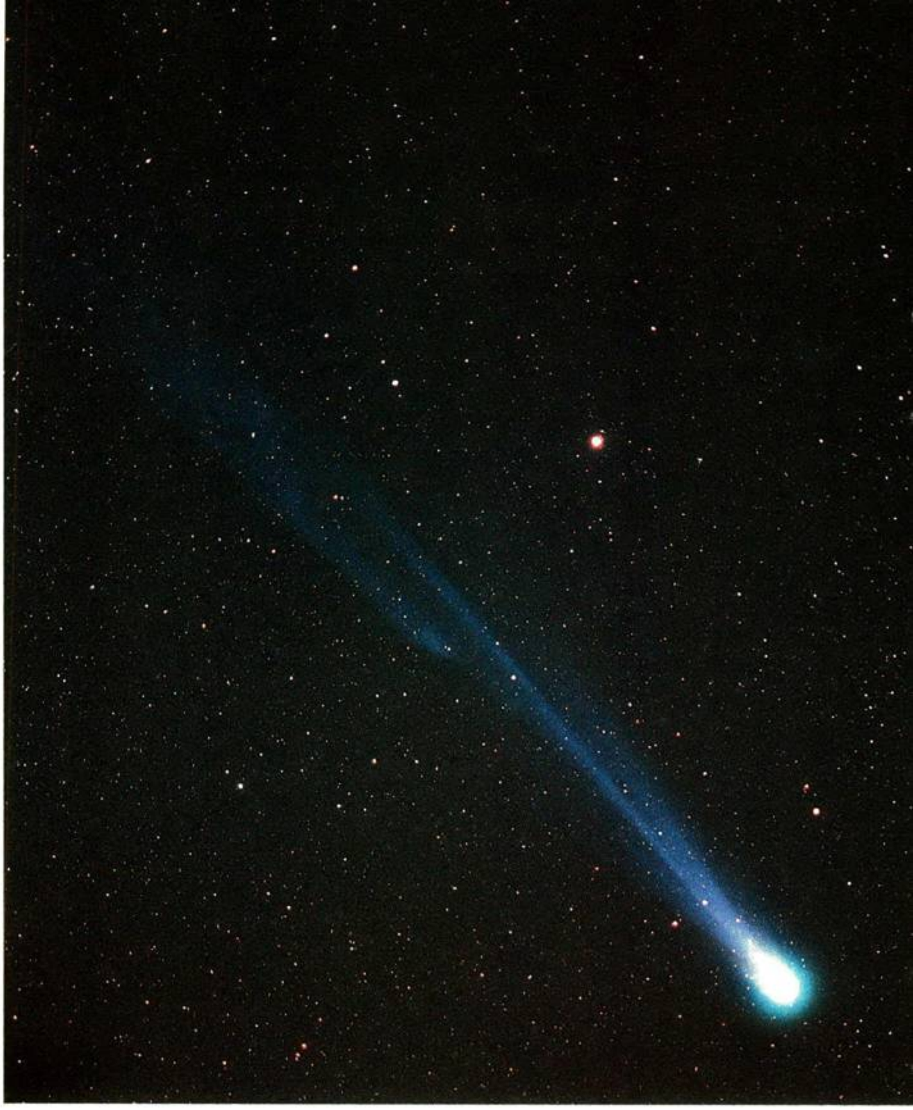
Mark Raddick

Bob & Janice Fera

LIKE A GIANT CIRCUMPOLAR HOUR HAND, Hyakutake never set after brushing to within 4° of Polaris on March 26 (below). The comet was also a breeze to follow through kite-shaped Bootes between March 20 and 23, an icon of spring with its fiery-orange star Arcturus (right).

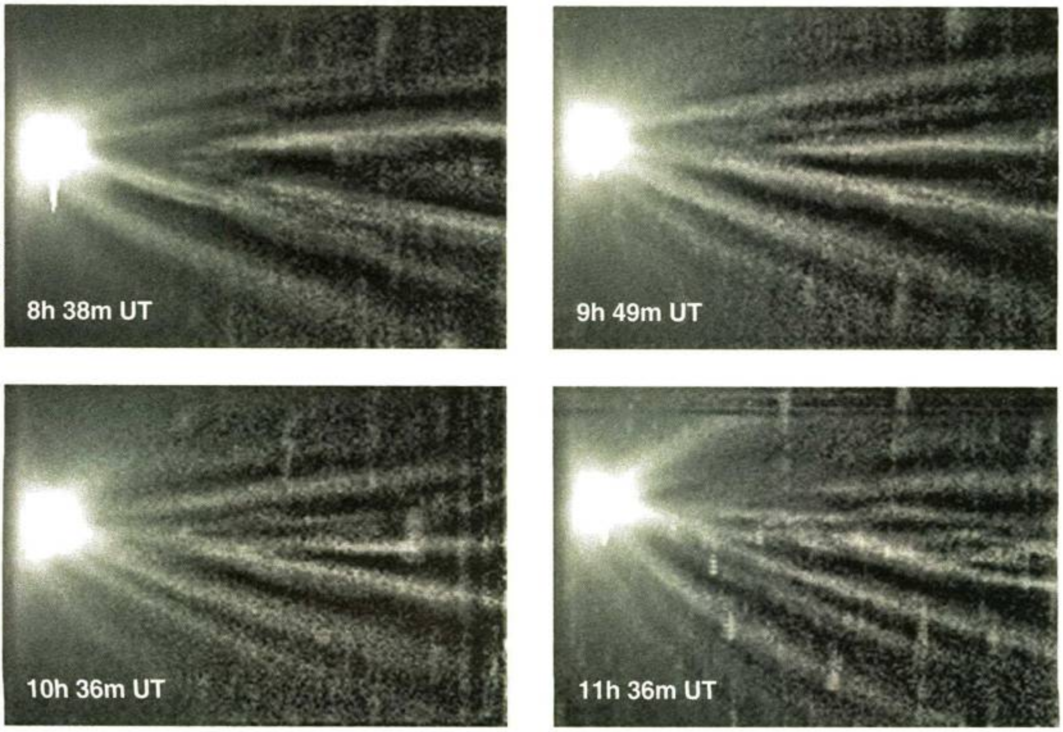


Scott Squires



Siegfried Manietta

THE CCD REVOLUTION FINALLY found its comet in Hyakutake. These electronic cameras routinely nabbed subtleties within arcseconds of the comet's nucleus. Here a series of frames 55" wide record ionized gas streaming away from Hyakutake's nuclear region over the course of two hours on March 21. That overexposed blob of light in each panel is the inner coma, a region of glowing gas that immediately surrounds the comparatively microscopic, effervescing nucleus. Bars extending down from the coma aren't real; the coma's shear brightness caused this CCD to "bloom" light onto adjacent pixels.



Richard Berry (4)

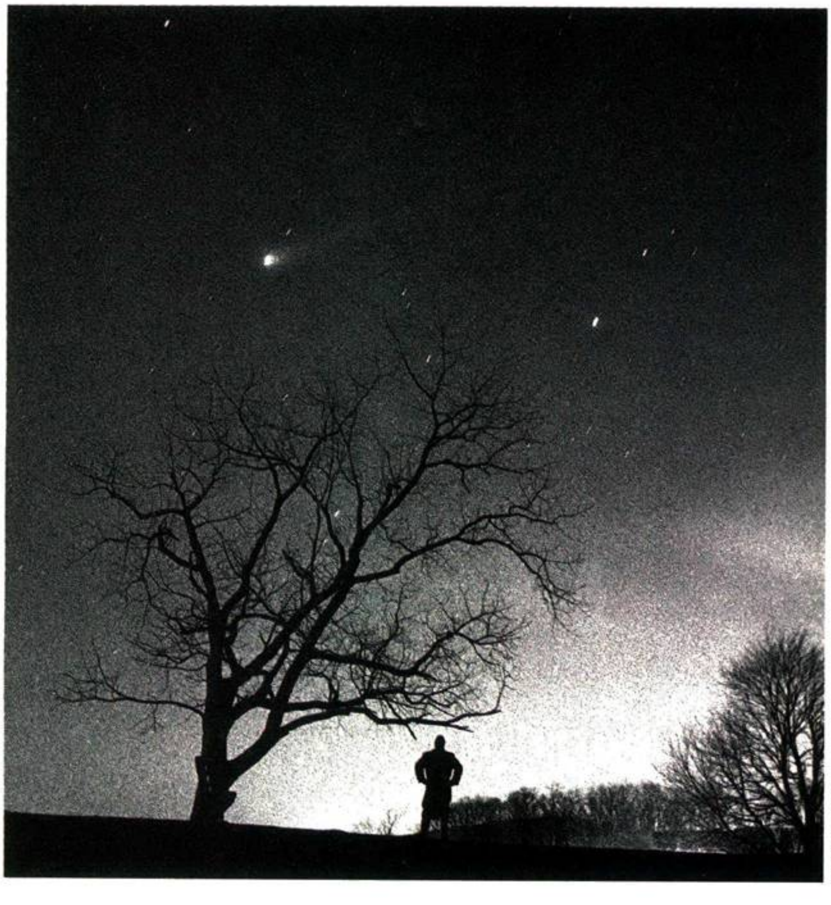
Ernest Sangraw

showed two curved jets emanating from the nucleus and rotating clockwise. From the pattern of rotation, Laurent Jorda and Jean Lecacheux conclude that the nucleus rotates every 6 hours or so, much faster than Comet Halley's 2-day rotation.

Besides Hubble and Pic du Midi, even casual amateur observers witnessed these jets and a high rate of activity, which betrayed that Hyakutake was a repeat performer. A comet that ventures into the inner solar system on many occasions develops a rigid crust of debris and refrozen ice. As the comet approaches the Sun, the intense heat warms up ices below the crust, causing them to erupt like a geyser. These geysers punch holes through the crust, forming the jets. "If this was the first trip around the Sun for Comet Hyakutake, then there wouldn't be this crust of rubble formed," explains Weaver. "You would get an even, uniform outflow instead of these jets."

Brian Marsden of the Harvard-Smithsonian Center for Astrophysics calculates that Comet Hyakutake's previous orbit had a period of about 8,000 years. In other words, the comet made its last apparition around 6,000 B.C., when our ancestors were experiencing the dawn of the agricultural revolution. But gravitational perturbations from the planets on this pass will stretch the comet's next orbit into a 16,000-year ellipse, meaning it won't make another pass through Earth's neighborhood until A.D. 18,000.

HYAKUTAKE REMINDED US that the seemingly unchanging sky still harbors surprises. This message is best summed up in a reader self-portrait taken on March 23 (below). We followed its growth from February's gas cloud into April's well-worn dusty phase (top). April's active nucleus dumped greater amounts of dust, which reflected sunlight for a yellower tail.



Mark Raddick

Déjà vu All Over Again

It's intriguing to think how our descendants might greet Hyakutake upon its return. Maybe our experiences will lie buried in the passage of time, overtaken by the daily demands of, say, interstellar travel. Then again, Hyakutake might amaze and surprise once more, an ageless echo of our own brand of humanity reacting to the unexpected.

For us in the late 20th century, though, it's time to look forward to the next cometary spectacular we fully expect. You remember Hale-Bopp's upcoming spring 1997 visit, don't you? As of July 1, there are only 305 days until it follows Hyakutake's lead and makes its own swing past the Sun.

Perhaps the best things in life might be predictable after all. ☐

Associate Editors John Shibley (jshibley@astronomy.com) and Robert Naeye (rnaeye@astronomy.com) sleeplessly enjoyed Comet Hyakutake's visit over Southeast Wisconsin.

Plunge into the Lagoon

A three-dimensional exploration of a giant star factory awaits you on any clear summer evening.

by David J. Eicher

Everyone knows the Lagoon. Visible to the naked eye as a cloudy spot, the much-observed emission nebula lies smack dab in the center of the Sagittarius Milky Way, forming one of the brightest and most visible crown jewels of the summer sky. It's easily in the top ten favorite deep-sky objects for Northern Hemisphere viewers.

But how many observers view this complex of stars, gas, and dust with a penetrating eye? How many viewers gaze deep into the Lagoon and mentally untangle the physical structure of this hotbed of young stars? A journey of the mind, aided by a modest size telescope, can transform this rich nebula from a two-dimensional splash of light into a three-dimensional star factory.

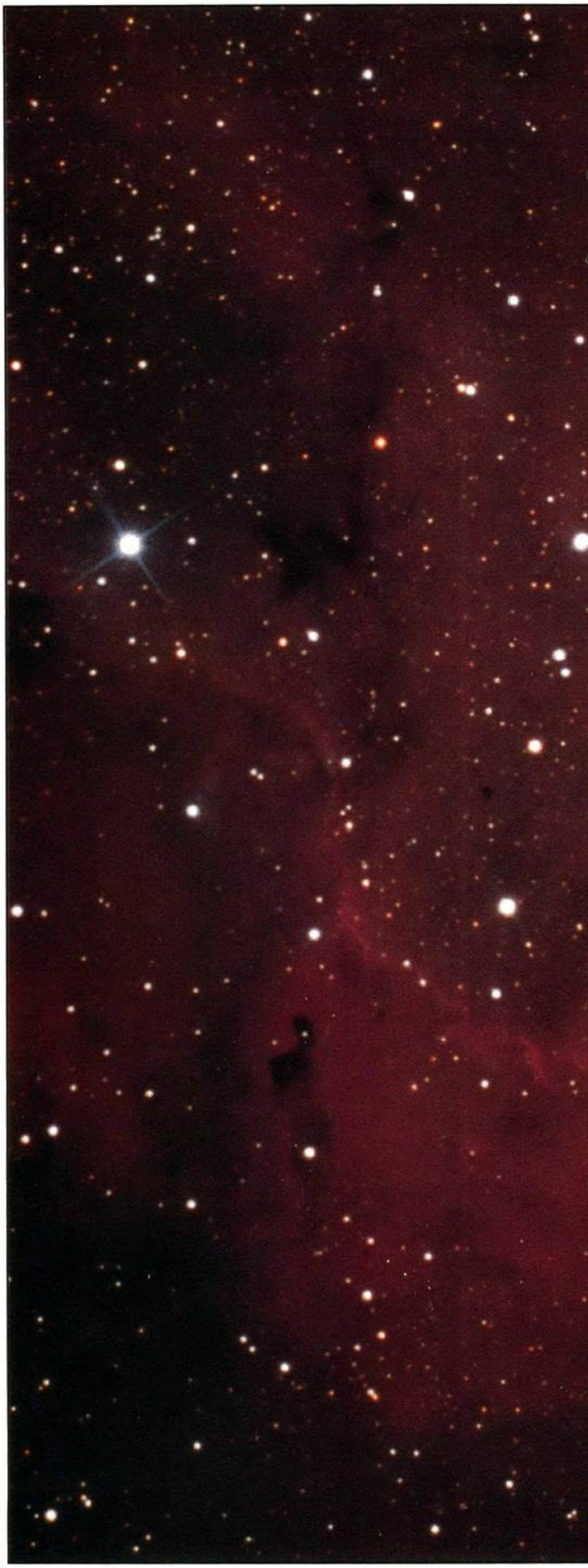
First, some basics. The Lagoon (M8, NGC 6523) is a cloud of hydrogen gas and dust that has gravitationally contracted into a clump. The Lagoon Nebula complex is about 5,200 light-years away, nearly toward the center of the Galaxy, which is hidden by obscuring dust and lies about 22,000 light-years beyond. Thus, the Lagoon offers Northern Hemisphere observers the most striking example of a star factory with an associated bright cluster they can see relatively close to the Sun.

You can plainly see one of its byproducts, the open cluster NGC 6530, visible as a splash of bright stars on the eastern edge of the nebula. To find it, aim your finder scope at Gamma (γ) Sagittarii, the 3rd-magni-

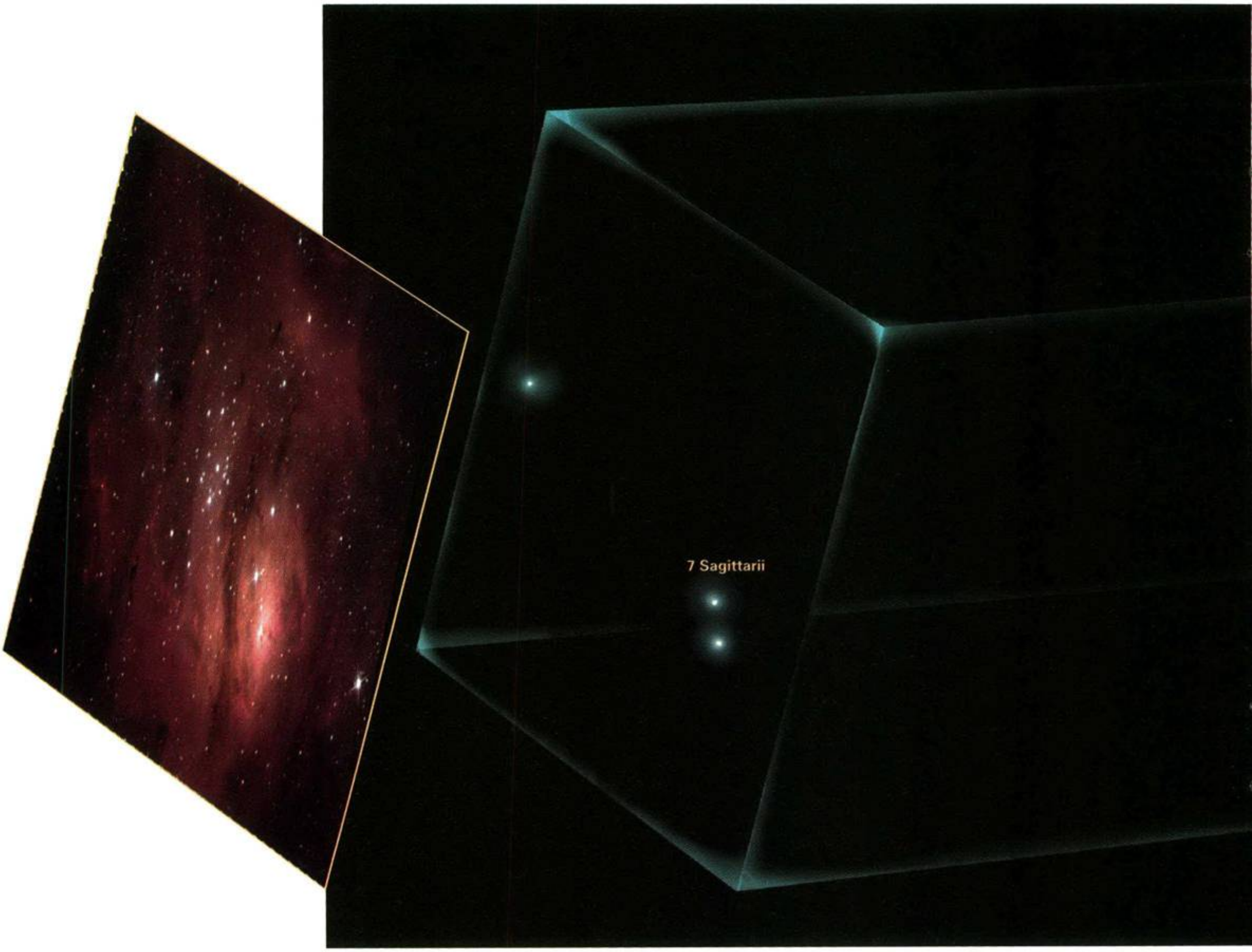
The Lagoon Nebula

(M8, NGC 6523)
Emission nebula
Size 90′ by 40′
Distance 5,200 light-years
Associated with the star cluster NGC 6530

NGC 6530
Open cluster
Magnitude 4.6
Size 15′
Distance 5,200 light-years
Age 2.0 million years
Brightest star mag. 6.9 type O5



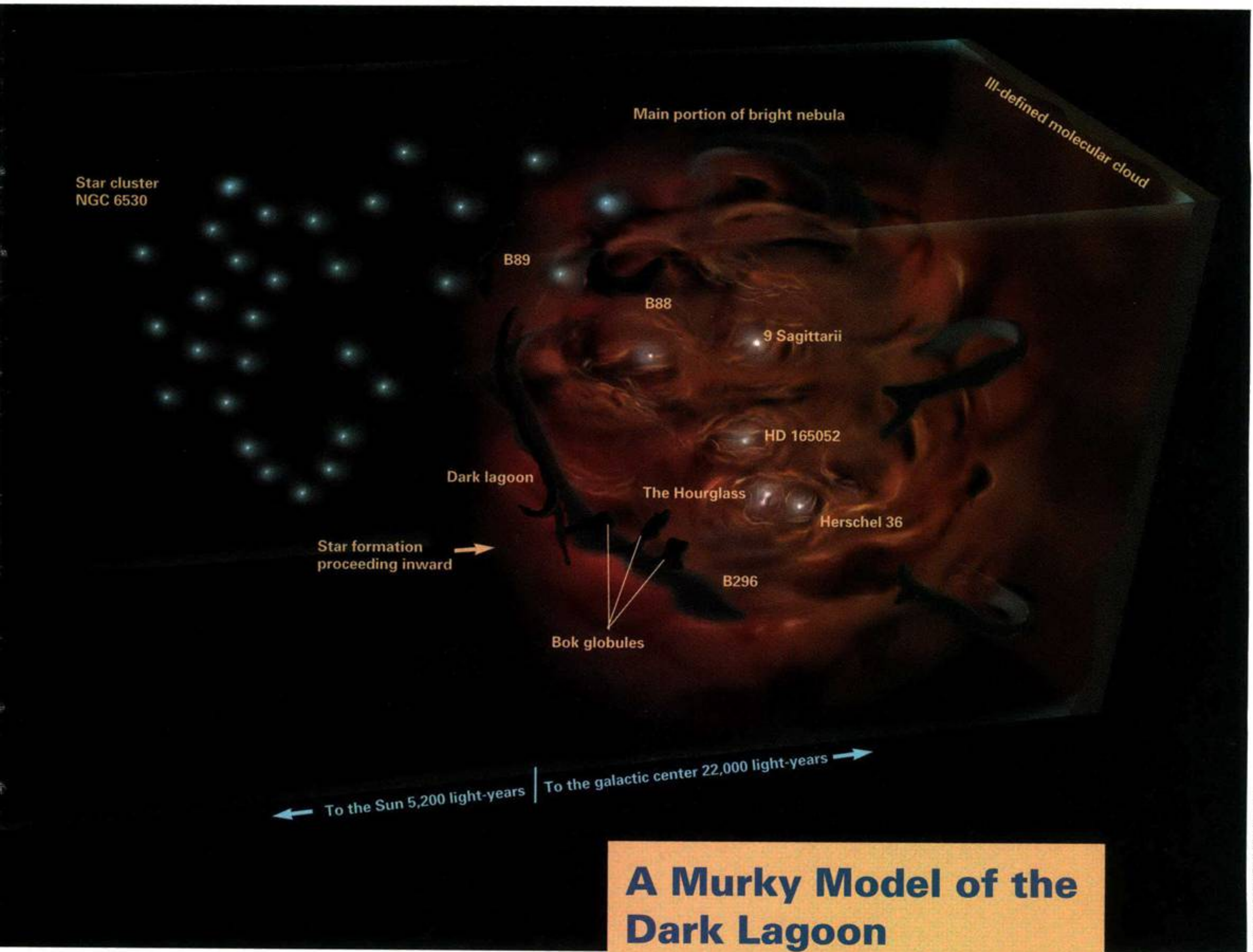
Andrew Peters



tude star marking the Teapot's spout, and move 6° north. The view is beautiful with any optical aid, appearing in large binoculars as a misty haze studded with faint stars. A 6-inch or 8-inch scope enhances the view into a bustling world of activity. The several dozen subgiant stars of NGC 6530 dominate the eastern half of the area, spilling out of even low-power fields. The cluster's brightest orb, one of many infant O-type (white, hot) stars in the field, shines at magnitude 6.9. A couple of dozen well-studied stars in the cluster are erratic T-Tauri type or flare stars, unstable babies that have not yet reached smooth nuclear burning in their cores. As you explore the greenish-white glow of the nebula itself, you'll spy two main portions of it. The brightest, circular patch of light on the western side of the nebula is striking and contains a sharply brighter center with several luminous stars involved. A winding, broad expanse of slightly fainter nebulosity stands aligned roughly north-south between the circular patch and the star cluster. The two main portions of the nebula are separated by a dark band, the "lagoon," that gives the nebula its name.

Larger telescopes and higher magnifications show some additional features in this area of rich astronomical activity. Fainter arcs and bands of glowing gas can be traced out to an area of 90' by 40', on all four sides of the two bright patches of nebulosity. Some of these extensions show sharp edges demarcated by wisps of dark nebulosity. Fine features inside the bright nebula can be observed on very dark nights: A 12-inch scope at high power shows thin ridges of gas spreading eastward from the dark lagoon, along the southern edge of the star cluster. High magnifications reveal small, dark areas that resemble fat fingers or bulbs of pitch black; these are Bok globules, dense clouds of dust and gas that are collapsing into newborn stars.

In the heart of the bright, circular area of gas, sharp-eyed observers can spot a tiny, dumbbell-shaped feature with a high surface brightness. This is the Hourglass, a knot of bright nebulosity. The many features associated with the Lagoon Nebula and its attendant star cluster indeed provides hours of opportunity for exploring, photographing, and sketching.


Main portion of bright nebula
Ill-defined molecular cloud
Star cluster NGC 6530
B89
B88
9 Sagittarii
HD 165052
Dark lagoon
The Hourglass
Herschel 36
Star formation proceeding inward
B296
Bok globules
To the Sun 5,200 light-years
To the galactic center 22,000 light-years

ASTRONOMY:Phil Kirchmeier

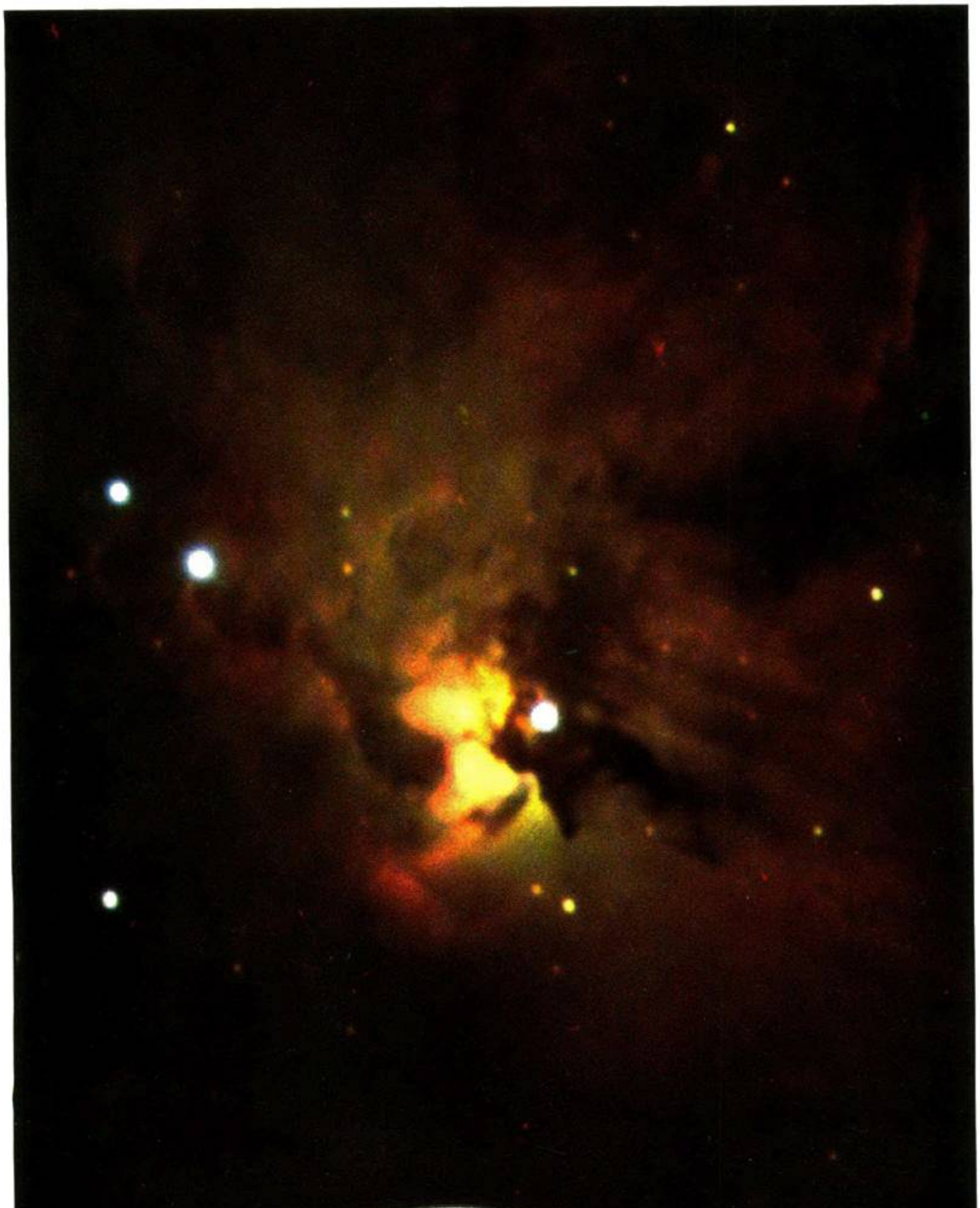
A Murky Model of the Dark Lagoon

Strictly speaking, the distances to various parts of the Lagoon Nebula complex are identical within the errors that astronomers can measure. Because star cluster NGC 6530 is relatively unreddened, however, astronomers can place it in the foreground. The nebula itself, slowly collapsing and forming stars, is a "blister" star factory in that the star formation began around the edges of a dense molecular cloud and is moving inward, eating the gas from the outside in.

The dense part of the cloud lies behind the cluster, and the nebula represents the glowing portion of the gas that remains. The brightest part of the nebula is called the Hourglass, a background object illuminated by the hot star Herschel 36, and other brilliant stars that light the cloud, including 9 Sagittarii and HD 165052. Tiny Bok globules, regions of dust perhaps 10,000 astronomical units across, float majestically in front of the nebula and are collapsing into infant stars.

Interpreting exactly what's going on in the Lagoon is a relatively new sport. The problem is that the distances to various parts of the Lagoon are identical within the errors that astronomers can measure. Some clues and recent studies are beginning to unravel the Lagoon's nature, however. The fact that NGC 6530 appears relatively unscathed by absorption — it has a "clean" color-magnitude diagram without differential reddening across the cluster — means that it sits in the foreground. Several other bright stars (and some faint ones, too) are foreground objects, like the ones flanking the brightest portions of nebulosity on the east and west and the bright star appearing in the northern part of the circular patch of nebulosity. These include 7 Sagittarii, a magnitude 5.3 type F3 main sequence star only 240 light-years away.

The nebula itself is a large bubble of gas and dust set against the backdrop of an immense, ill-defined molecular cloud. Astronomers believe the Lagoon is a "blister" star factory; the star formation is occurring from the outside in, having begun on the fringes of the bubble and working its way in toward the center. As



THE HOURGLASS is the brightest knot of gas near the Lagoon Nebula's center. The brilliant glow of the gas is powered by the intensely hot star Herschel 36, visible to the right of the Hourglass.

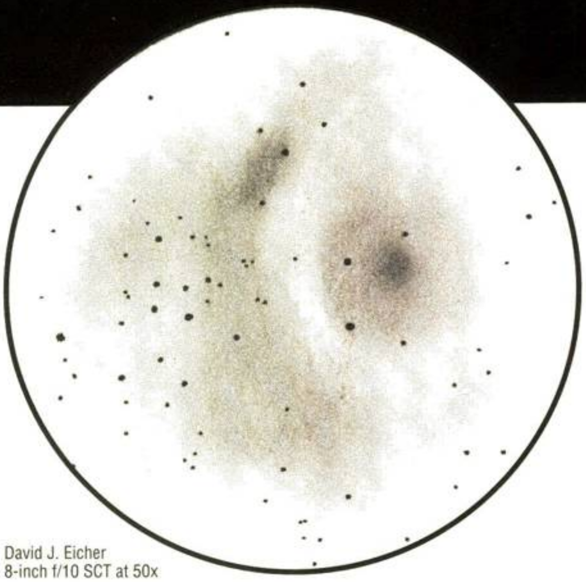
Lick Observatory

the star factory continues to eat away the gas, adding more young, hot stars to the cluster, the shape of the nebula will change. The glowing parts of the gas we see are fluorescing like a gardener's grow-light, their molecules excited by the intense bath of radiation streaming onto them from the brilliant, nearby stars. Many of the Bok globules appear to float in front of bright areas of gas; they are foreground objects visible only against the glowing backdrop of the nebula itself. Many others are invisible because they are not silhouetted by bright parts of the nebula. Prominent among these dark features are Barnard 88 (northern edge), Barnard 89 (eastern side), and Barnard 296 (southern edge).

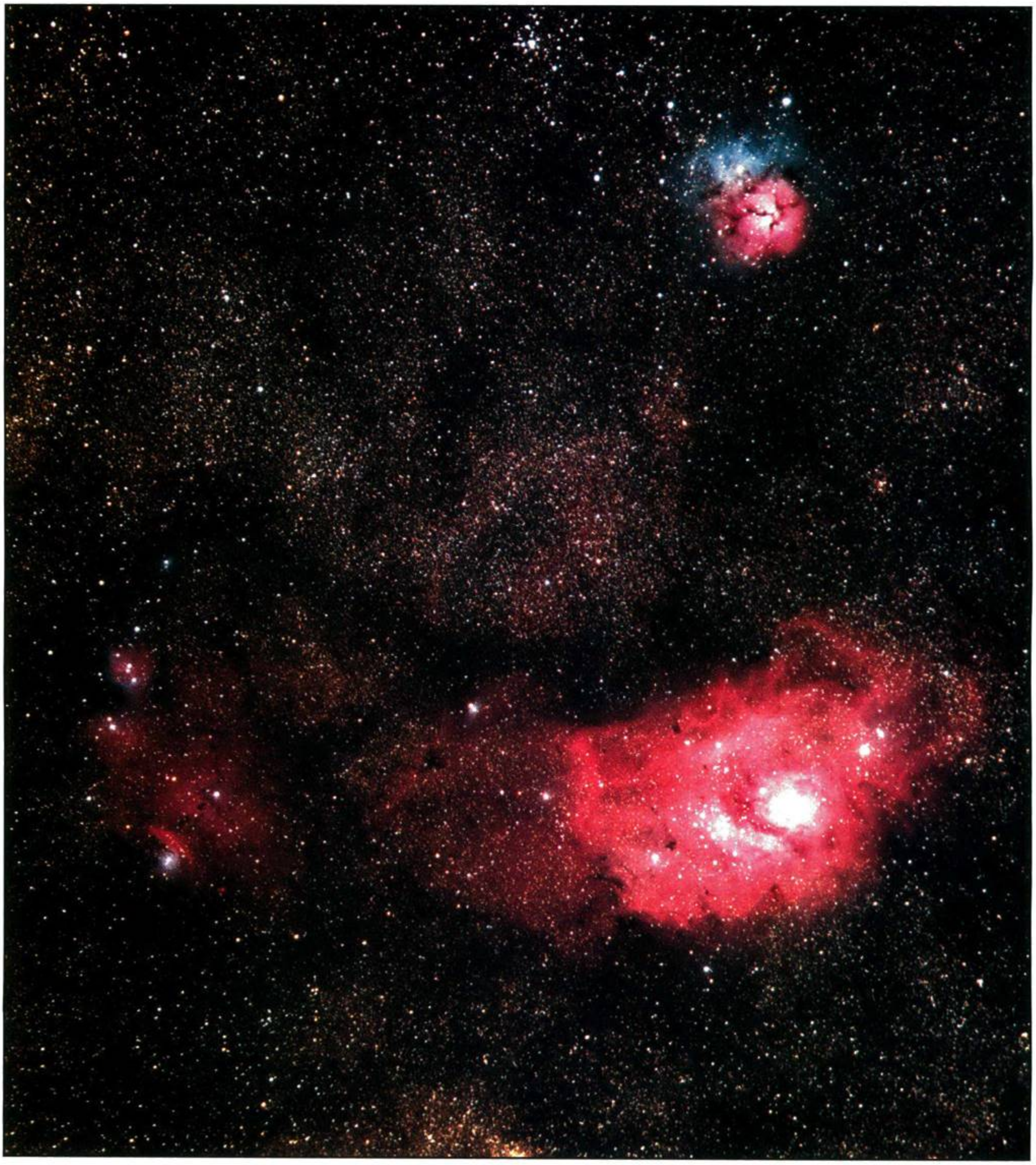
Moving inside the nebula, astronomers have pinned down the approximate position of the Hourglass, an intensely bright knot of nebulosity spanning only 30" and powered by the nearby star Herschel 36, the 9th-magnitude O7 star located in a small dark cloud just west of the Hourglass. This detail, deep inside the central portions of the Lagoon Nebula, would be invisible but for the fact that the star-forming process has gouged a cavity into the bubble, exposing these features to us.

The brightest star in the field, 3' east-northeast of the Hourglass, is 6th-magnitude 9 Sagittarii, a hot, O5 star that appears to be the main illuminating source in the nebula (although other young stars obscured by dust also power the Lagoon's light). Prominent among these is HD 165052, a 7th-magnitude type O7 star on the eastern side of the dark lagoon. Behind central details like the Hourglass lie numerous features blocked by dust, all set against the wash of a hazy cloud of dusty molecules in the background.

When exploring these features by telescope, consider their immense physical sizes. End to end, the nebula spans at least 120 light-years, meaning that light from one side that reached the other this morn-



David J. Eicher
8-inch f/10 SCT at 50x



Luke Dodd

THE LAGOON NEBULA REGION is extraordinarily rich in dust and gas, featuring the Trifid Nebula (M20) north of the Lagoon and an intricate network of dark nebulosity intertwined with clouds of bright glowing gas.

ing commenced its journey when the presidential candidates were not Bill Clinton and Bob Dole but Rutherford B. Hayes and Samuel J. Tilden. Individual features in the Lagoon can be much smaller, however: the Bok globules measure on the order of 10,000 astronomical units across, smaller than the solar system.

In this playground of stars, gas, and dust, backyard astronomers can see the basic processes of the universe at work. Scrapped matter from old suns recycled into new stars reveals the conservation of matter on the most comprehensible level. And a better look at this rebirth than in the Lagoon Nebula just doesn't exist. ☐

Dave Eicher has been observing deep-sky objects ever since he founded Deep Sky Monthly *at age 15.*

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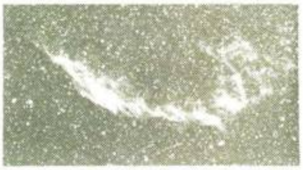

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Electric Vacuum Pump, Model R-10 **$325**

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All **LUMICON EASY-GUIDER™** off-axis guiders† have both radial and 360° rotational adjustments for 5X easier guide-star selection, use 48mm filters, 360° camera rotation, large prisms for bright guide-stars. †U.S. Patent 4,448,500
Specify Camera and Telescope type.

NEWTONIAN EASY-GUIDER™

Full aperture. Installs in seconds. Specify 2" or 1¼".

NEWTONIAN EASY-GUIDER **$189.50**
48mm Coma corrector/field flattener **$285**
3X Relay Diagonal (see photo) **$99.50**
Illuminated reticle eyepiece, pulsed **$109.50**
Guider for Hasselblad **$409,** Mamiya 645 **$199**
Pentax 6X7 **add $119;** Pentax 645 **add $139**

CASSEGRAIN EASY-GUIDER™

For C-8, Meade 2080, Cynamax-8. Includes 50mm achromatic lens for f/5.8 operation—3X shorter exposures! **Superb rich field viewing, too!**

CASSEGRAIN EASY-GUIDER **$249.00**
Adapter for Hasselblad **$225,** Mamiya 645 **$98**
Pentax 6X7 **add $119;** Pentax 645 **add $139**

GIANT EASY-GUIDER™

For Celestron-11, C-14, and the 10-12" Meade. Includes 80mm clear aperture achromatic lens for edge-to-edge illumination & pin-point star images. F-ratio adjustable f/4-f/11. **Also yields unmatched Rich-Field viewing.**

GIANT EASY-GUIDER **$395.00**
48mm DEEP-SKY Filter ordered with any EASY-GUIDER (SAVE $20) ...... **add $99.95**
Adapter for Hasselblad **$295,** Mamiya 645 **$149**
Pentax 6X7 **add $129;** Pentax 645 **add $149**

WHAT DO YOU NEED?

1. **Illuminated reticle eyepiece** ... **$109.50** Lumicon 12mm eyepiece system has adjustable LED illumination, dual crosslines, pulsed.
2. **Cable release** for long exposures **$9.95**
3. **Declination motor** (state telescope type) **$109**
4. **Dual-axis drive corrector** for telescope. This should be part of the telescope when purchased. Call LUMICON for details.
5. **LUMICON EASY-GUIDER** (selection to left)
6. **LUMICON 48mm DEEP-SKY FILTER $119.50** This is essential for highest possible contrast. Contrast is boosted up to 3X for ***both*** color or black & white photos. The 3 photos in this ad showing the Helix Nebula, Horsehead Nebula and Veil Nebula were all made using a LUMICON 48mm DEEP-SKY FILTER.
7. **Hypersensitized film.** Purchase from LUMICON or make your own with a LUMICON HYPER-KIT.

HYPERSENSITIZED FILM

SR1600
Scotch
1000

HYPERED FILM IS 2-10X FASTER!

LUMICON Hypersensitized film is essential for good deep-sky astrophotography. Deduct 10% for 3 or more rolls (mixed o.k.). ***No C.O.D.s.***

Film Type, 35mm	**Exposures**	**Price**
2415, Ultra-fine B&W, red sens.	36	**$11.95**
SR-G3200, fastest of all, color neg	24	**$14.95**
Kodak Gold 1000 fast, fine grain	12	**$13.95**
Fuji G800 fine grain color neg.	**24**	**$13.95**
Ektachrome 1600, fast slide film	24	**$14.95**
Fujichrome RD100, fine grain slide	24	**$12.95**
D-19 B&W Developer	1 gal.	**$6.95**

LUMICON® ACCESSORIES MEADE® TELESCOPES

TOLL-FREE ORDER LINE 1-800-767-9576 EXPERT INFORMATION 1-510-447-9570 FAX 1-510-447-9589
LUMICON, 2111 Research Drive, Suites 4-5, Livermore, CA 94550 OPEN M-F 9-5, SAT 9-1 PST

LED FLASHLIGHT . $14.95

LUMICON LUMILITE™ Red LED Flashlight

This red LED flashlight preserves night vision. It uses 2 AA cells (included!) which last 60-100 hours.

LUMILITE red LED flashlight **$14.95**

DRIVE CORRECTORS

LUMICON
UNITRAK

LUMICON UNITRAK
DRIVE CORRECTOR

Operate your telescopes ***anywhere!*** Use the single-axis Unitrak with a 12V DC car battery. The dual-axis drives are for photography and use either 12V DC or 125V AC.

Unitrak™ single-axis corrector	**$99.95**
Convenient rechargeable Porta-Pac battery: 12V DC Porta-Pac (5AH) & recharger	**$89.50**

48MM COLORED FILTERS

FOR EVERY NEED

Select 48mm UV, Red, Yellow, Green (ea.)	**$24.00**
48mm Cyan (absorbs red)	**$69.00**
48mm High Performance Blue (95% T)	**$59.00**
48mm Tri-Color Blue (80% T- 400nm) .	**$59.00**
48mm Ultraviolet (85% T- 370nm)	**$59.00**
Color Separation Set: cyan, red, yellow, blue	**$159**

RICH FIELD! 2° in 8'' SCT

NOW ONLY
$99.50

LUMICON Rich-Field Viewer on C-8 with LUMICON 2'' star diagonal and 2'' eyepiece.

The LUMICON Rich-Field Viewer fits **all** commercial Schmidt-Cassegrain telescopes. It has a high-performance coated achromatic focal reducing lens with 50mm or 80mm clear aperture for **totally unvignetted viewing** with 2'' or 1¼'' eyepieces. It is available in several combinations depending on the eyepiece and field-of-view you desire (see chart below).

LUMICON Rich-Field Viewer	**$99.50**
Giant Rich-Field Viewer (10-14'') ..	**$250.00**

Optional Eyepiece	**TRUE FIELD**	**Price**
Meade 32mm Plossl	1.4°	**add $99**
Meade 32mm 2'' Wide-Field†	1.9°	**add $459**
Meade 40mm 2'' Wide-Field†	2.4°	**add $519**

†*Includes 2'' enhanced aluminum Star Diagonal (may not reach focus on some telescopes).*

PROTECTIVE DUST COVERS

Protect your valuable telescope optics, eyepieces and accessories with these black vinyl covers. Add $1 shipping. Deduct 10%, 2 or more sets.

1¼'' O.D. plug, seals focuser			**4/$2**
2'' O.D. plug	**2/$2**	3½'' O.D. plug	**$1.50**
1¼'', 1⅜'' ...	**3/$2**	7½''	**$10**
1½''	**2/$2**	9½'', 10.4''*	**$15**
2''	**2/$2**	12½'', 12⅞''* ...	**$20**
2⅛''	**2/$20**	15.0'', 15.6'', 16''*	**$28**
5½''	**$6**	19'' (DS-16)	**$35**
*Fits Odyssey		21'' (Odyssey-II)	**$35**

MEADE 7'' - 16'' LX200

NEW! 7'' - 10'' LX50

8'' LX50
$1395

16'' LX200 $14,950

Meade 8'' LX200 Telescopes

LX50 - includes dec. motor, hand controller.
LX200 - full computer control w/64K obj. mem.
Tripod: extra for LX50; included for LX200
NOTE: A wedge is **not** needed for visual observing with the LX200 Drive. Select f/10 or f/6.3 (no extra charge) for your LX200.

NEW! 8'' LX50 w/wedge, dec. motor, hand controller ($105 P&S)	**$1395**
Tripod for 8'', 10'' LX50 ($30 P&S)	**$295**
8'' LX200 w/computer ($105 P&S)	**$2795**
Wedge for photographing w/8'' LX200 ..	**$139**
7'' LX50 f/15 Maksutov w/wedge ($125 P&S)	**$1795**
10'' LX50, f/10 w/wedge, dec. motor, hand controller ($145 P&S)	**$1695**
10'' LX200 w/computer ($145 P&S)	**$3195**
12'' LX200 (f/10 only)($215 P&S)	**$4495**
Super Wedge for photogr. w/10'',12'' LX200	**$395**
16'' LX200 f/10 w/tripod ($385 P&S) .	**$14,950**
Dew Shields: 8'' ..... **$119;** 10''	**$129**
12'' .... **$189;** 16''	**$289**

OTHER SCHMIDT-CASSEGRAINS

Meade 2045D 4'' f/10 w/motor ($40 P&S)	**$699**
Model 2120B 10'' w/wedge, tripod ($75)	**$1699**

PHOTOGRAPHY ACCESSORIES

Cassegrain EASY-GUIDER 4'', 8'', f/6 or f/10	**$249**
Giant EASY-GUIDER for 10''/12'' f/4-f/10 .	**$395**

MEADE STARFINDERS

8'' f/6
$749

New 8'' f/6 Meade Starfinder telescopes

See the Meade ad in this magazine for full descriptions. These are complete telescope systems with motor drive & finderscope (equat. only), mount, and 25mm (=48X) eyepiece. New DC motor runs on 4AA batteries.

6'' f/8 Dobsonian Starfinder ($46 P&S)	**$349**
6'' f/8 Equat. Starfinder 6(add $79 P&S) ...	**$649**
8'' f/6 Dobsonian Starfinder (add $59 P&S)	**$469**
8'' f/6 Equat. Starfinder 8 (add $89 P&S) ...	**$749**
10'' f/4.5 Dobsonian Starfinder ($85 P&S) ..	**$649**
10'' f/4.5 Equat. Starfinder 10 (add $99 P&S)	**$879**
12.5'' f/4.8 Dobsonian Starfinder ($95 P&S)	**$895**
16'' f/4.5 Dobsonian Starfinder (freight COD)	**$1195**
16'' f/4.5 Starfinder 16 (ship. freight COD) .	**$2695**

*All Starfinder telescopes shipped directly from Meade to the purchaser. Please add the indicated packing & shipping charge to the price. Slightly lower P&S for payment by check. LUMICON showroom prices are $50-$100 higher.

ACCESSORIES

LUMICON carries all Meade accessories.

LUMICON Single axis drive corrector .	**$99**
Magellan computer; specify Dob. or Eq. ($15 ship)	**$295**
Meade 47M Dual-axis drive corrector with tangent arm & electric declination ..	**$475**

SKY VECTOR™ $299!!

Includes Computer, Encoders, Hardware

LOW PRICE—from $299

LUMICON SKY VECTOR FEATURES:

- "GUIDE" mode leads you to object
- Digital right ascension readout to 1 min.
- Digital decl. readout to 10 arc-min.
- 4000 pulse (0.09° accuracy) encoders
- Polar alignment ***not required!***
- Motor drive ***not required!***
- Just sight two stars to align!
- Works **equally well** for alt-azimuth telescopes like Coulter Odyssey and equatorial mounts like C-8, Meade 2080.
- **No need** to enter latitude, longitude, etc.

SKY VECTOR I™ $299

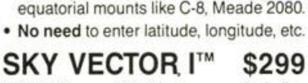
NEW! With over 220 object memory including the 110 Messier and 58 best NGC objects.

SKY VECTOR II™ $349

IMPROVED — Planets, Over 3,700 Objects! With size, magnitude and full visual description.

NGC SKY VECTOR™ $439

IMPROVED!—5500 Additions / Corrections



NGC SKY VECTOR with IDENTIFY (Sky Tour) mode, 12,000 object memory including the corrected RNGC catalogue, IC catalogue, P&K planetary catalogue, & much more!

Specify Telescope Type: Meade 2045, 2080, 2120, C-8, C-11, Odyssey 8, 10, 13, 17½, Alt-Azimuth, Meade 6-16'' Dobsonian.

Ultima 8, 9¼, 11 **add $25**, C-14 **add $75**

COMA CORRECTOR

Coma 1 inch off-axis 17½'' f/4.5

Same field with LUMICON coma corrector; smaller, more numerous stars.

This computer-designed LUMICON 2'' lens reduces coma and flattens the field for both viewing and photography. **It threads into LUMICON 2'' EASY-GUIDERS for effortless installation.** This zero power lens does not change image scale nor shift focus, and all lens surfaces are multi-coated for highest efficiency. Clear aperture = 1.8''.

LUMICON 48mm Coma Corrector/Field Flattener Lens	**$285.00**
LUMICON 2'' EASY-GUIDER .	**$189.50**
2'' EASY-GUIDER (Mamiya 645)	**$239.50**
2'' Adapter for Pentax 6X7 ...	**$129.00**
2'' Adapter for Hasselblad .	**$229.00**
2'' Adapter for Bronica SQ-A	**$175.00**
2'' Extension for viewing ...	**$26.00**

2'' DELUXE BARLOW

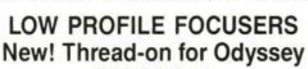
1.8x Multiplier Lens (2'' Barlow)

LUMICON 1.8x Multiplier Lens (2'' Barlow)	**$259.00**

LUMICON ACCESSORIES

LUMICON, Livermore, CA 94550 (510) 447-9570 FAX (510) 447-9589

LARGE UV/DUST SEAL



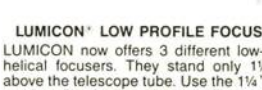
Protect the optics of your 8-14'' Schmidt-Cassegrain with a UV/Dust Seal. Simply thread it onto the rear cell, then attach all normal accessories. The large size fits Meade 2120, Celestron-11 and -14 & has a high quality multi coated (removable) 72mm UV filter.

Deep-Sky Filter/Dust Seal for C-8, 2080 ...	**$119.50**
UV/Dust Deal for Celestron C-8 ...	**$39.00**
UV/Dust Seal for Meade 2080, 2045	**$39.00**
UV/Dust Seal (large) for Meade 2120	**$89.50**
UV/Dust Seal for Celestron-11, -14 .	**$89.50**

LOW PROFILE FOCUSERS

New! Thread-on for Odyssey

FROM $69.50



LUMICON® LOW PROFILE FOCUSERS

LUMICON now offers 3 different low-profile helical focusers. They stand only 1¼-1½'' above the telescope tube. Use the 1¼'' or 2'' versions for viewing. Use the 2'' non-rotating focuser for convenient photography with the LUMICON 2'' EASY-GUIDER™.

Select your desired base-plate shape! Coulter Odyssey (thread-on installation), Flat, 7'' OD, 9½'' OD, 12½'' OD, 16'' OD, 21'' OD.

LUMICON 1¼'' Helical Focuser	**$69.50**
LUMICON 2'' Helical Focuser 1½'' high	**$75.00**
LUMICON Non-rotating Helical Focuser	**$129.00**
2'' Astro Systems focuser, only 2'' high	**$139.00**
3 handles for non-rotating focuser	**$12.95**
2''/1¼'' adapter w/48mm filter threads	**$20.00**
2'' LUMICON EASY-GUIDER	**$189.50**

LUMICON 50mm, 80mm SUPER-FINDER™

Visual Astronomers prefer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat or 50mm, F=200mm coated achromat. Eyepieces and/or star diagonal are extra.

1¼'' 50mm Finderscope **$69.50**, right-angle	**$69.50**
1¼'' straight-thru 80mm SUPER-FINDER .	**$189.50**
1¼'' right-angle 80mm SUPER-FINDER ..	**$199.50**
1¼'' right-angle version, w/star diagonal ..	**$239.50**
25mm Cross-hair 1¼'' eyepiece (12X)	**$59.00**
Large mounting rings for 80mm Finder	**$55.00**
1¼'' Star Diagonal **$49**, Mounting Brackets,	**$39.50**
1¼'' 45° diagonal for correct left-right views	**$59.50**

LOTS OF ADAPTERS

2'' adapter for C-8, Meade 2080, etc. ..	**$29.50**
2'' adapter for C-80, C-100 refractor ...	**$39.50**
2'' adapter for C-70, C-80F, C-100F fluorite	**$39.50**
2'' adapter for C-6, Comet Catcher, Meade 312	**$30.00**

EXTENSION TUBES

1'' long 1¼'' OD thread-in extension ...	**12.00**
2½'' long extension (holds 1¼'' filters) .	**19.50**
4½'' long extension for 1¼'' eyepieces	**$29.00**
3'' long extension for 2'' eyepieces* ..	**$29.00**
2'' long extension for 2'' eyepieces* ..	**$29.00**

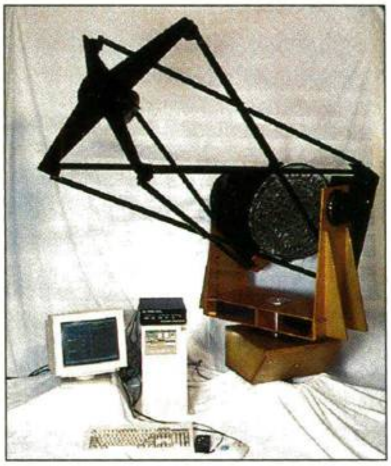
VIEWING ADAPTERS

2''/1¼'' reducing bushing, threaded 48mm*	**$25.00**
2''/T-thread adapter, threaded 48mm* ..	**$25.00**
T-thread/1¼'' adapter	**$25.00**
F/10 2'' or 1¼'' eyepiece viewing adapter for Giant Easy-Guider	**$39.50**
Low profile star diagonal eyepiece holder	**$16.00**
Meade 2'' Diagonal/Giant Easy-Guider	**$39.50**

**Threaded to hold 48mm filters.*

NEW PRODUCTS

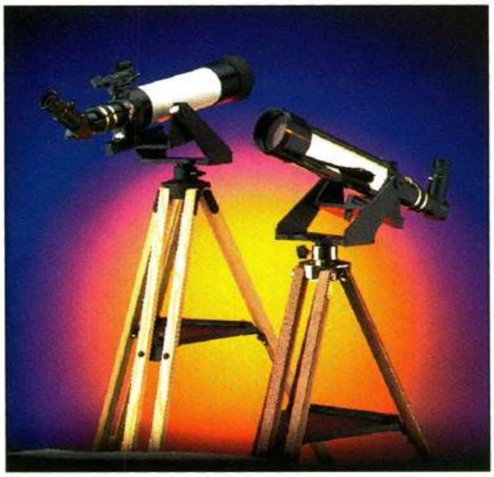
Computer-controlled Cassegrain Telescopes



Torus Precision Optics offers a series of open truss telescopes, available in a variety of customer-specified focal ratios in apertures from 0.4 to 1.5 meters. Pictured is a 0.5-meter f/10 classical Cassegrain on an alt-azimuth fork mount with Coude' focus. Ritchey-Chretien optics and equatorial fork mounts are also marketed. The optics feature Hextek gas-fusion primary mirrors, which have honeycomb centers sandwiched between front and back plates. This design affords the lightest possible weight while preserving extreme rigidity. Each optic comes with interferometric certification. The mount is constructed from anodized 6061-T6 aluminum alloy with stainless steel shafts, and has zero backlash friction drives. The motion control system runs off an IBM compatible 486DX2 computer that comes with the telescope. Torus offers three controller software packages with various levels of sophistication and capability. Torus also has an optional field derotator.

Torus Precision Optics, Inc., 67 Bon-Aire, Iowa City, IA 52240; (319) 354-1410; e-mail, torusopt@aol.com; http://www.avalon.net/~apeerystar/torus.htm. Prices start at $26,500 for a 0.4-meter instrument.

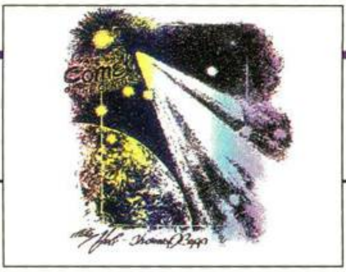
Ranger Telescope



Tele Vue introduces Ranger, a variant of the popular Pronto refractor. Like the Pronto, Ranger has a 480mm f/6.8 ED objective, but features a two-stage 1 ¼-inch focuser that incorporates a sliding tube for rough focus and a helical "thumb-wheel" mechanism for fine focus. Ranger also weighs in at a lighter 3 ½ pounds. Ranger's features include a snap-on lens cover, threads that accept 77mm filters, black anodized aluminum cells, a sliding dove-tail balance bar, and a powder-coated ivory-colored tube. Options include traveling bag, camera adapter, rubber glare shield, polished brass tube, 45° star diagonal, and straight-through prism. Ranger mounts easily to all camera tripods as well as Tele Vue's Panoramic and Gibraltar mounts.

Tele Vue Optics, Inc. 100 Route 59, Suffern, NY 10901; (914) 357-9522. Ranger telescope: $995

New Products presents announcements issued by manufacturers. ASTRONOMY assumes no responsibility for the product information supplied. Prices are suggested retail. Suppliers should send announcements and color photographs to the attention of John Shibley, P.O. Box 1612, Waukesha, WI 53187, or newprod@astronomy.com.



Hale-Bopp Tee-shirt

The El Valle Astronomers out of New Mexico market this Hale-Bopp tee-shirt as a fundraiser. It shows a rendering of Comet Hale-Bopp flying past Earth, along with signatures of the comet's co-discoverers, Alan Hale and Thomas Bopp. The royal-blue design, with splashes of magenta and yellow tones, is printed on off-white cotton. Sizes range in small to extra-extra large.

El Valle Astronomers, P.O. Box 126, Embudo, NM 87531-1026; (505) 579-4604 or (505) 852-2485; fax, (505) 852-2550. Hale-Bopp tee-shirt: $17.95 plus $3 shipping and handling; add $1 shipping per shirt for orders over two shirts. Specify size. All major credit cards accepted.

Astronomical Mood Music

Canadian amateur astronomer and musician John Nemy wrote, performed, and produced this 43-minute CD of astronomical mood music. Some of the 12 tracks include titles like "The Realm of the Galaxies," "Aquila," and "Lanterns in the Treetops." Songs are scored for synthesizer and have a distinct new-age style. Nemy even provided astrophotography for the cover and its liner notes.

Lynn Valley Recordings, 1493 Crown St., North Vancouver, BC, V7J 1G4, Canada; (800) 662-4033; fax, (604) 990-9178. Six Billion Suns CD: $20 US.

JOHN NEMY
six billion suns
six billion suns

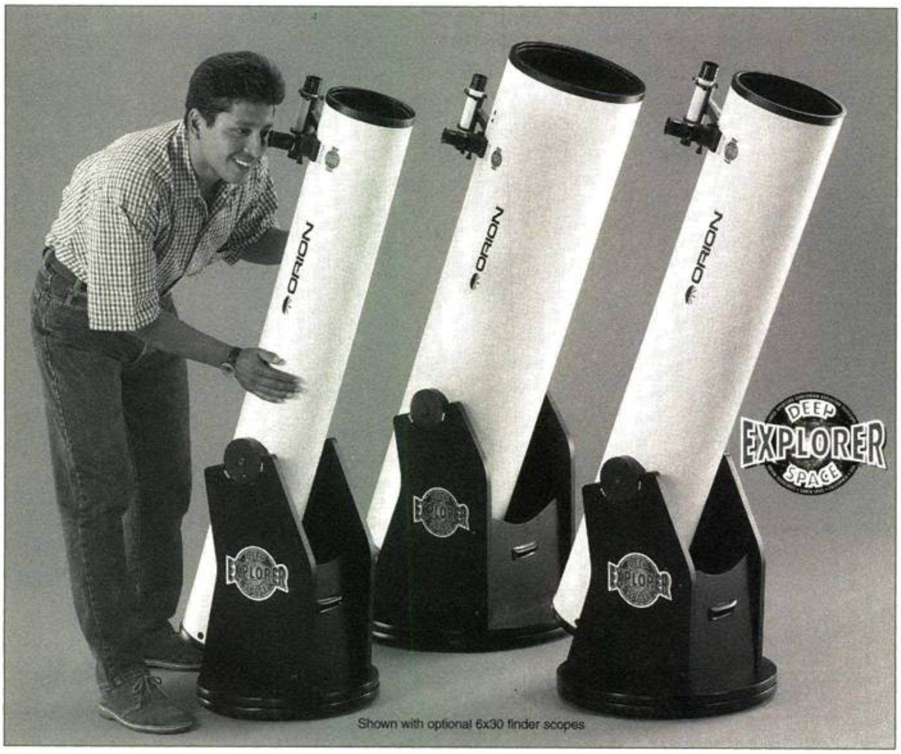
ORION
TELESCOPE CENTER

THE LARGEST CATALOG OF TELESCOPES, BINOCULARS, AND ACCESSORIES FOR AMATEUR ASTRONOMERS!

Everything You Need For Super Summer Stargazing

Turn for 2 pages packed with more great products . . .

Quality Telescopes from Orion®



Shown with optional 6x30 finder scopes

Orion Deep Space Explorer Dobsonian Telescopes

"Affordable, easy-to-use telescopes with sharp optics and sturdy mounts." Astronomy *(12/93)*

6", 8", & 10" Orion Deep Space Explorers

Our Deep Space Explorer Dobsonians are the "gold standard" in high-performance, low-cost telescopes. Their clean simplicity, rugged durability, and uncompromising optical quality make them ideal for both beginning and intermediate skygazers. We guarantee our precision Newtonian optical system will match or outperform those in other Dobsonian brands selling for much more. It delivers bright, jaw-dropping views of the heavens—you'll be impressed! The wood cabinet Dobsonian mount features zero-backlash teflon bearings for effortless telescope movement, making it easy to manually track objects. Each scope comes equipped with an aluminum low-profile helical focuser and a fully coated 26mm Sirius Plössl1.25" eyepiece. As an added bonus, we're including FREE a 5x finder scope and mounting bracket—a terrific value! So what are you waiting for—order a Deep Space Explorer today!

Now with FREE 5x Finder Scope!

6" f/8	#9901 **$319** (39.00)
8" f/6	#9902 **$419** (49.00)
10" f/4.5	#9905 **$599** (69.00)

10", 12.5", & 16" Premium Deep Space Explorers

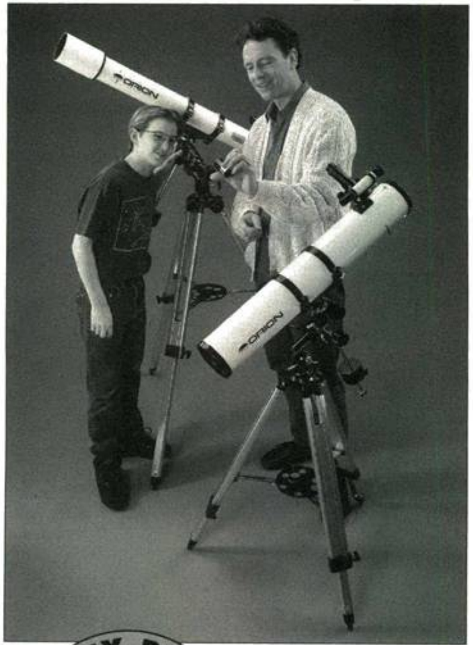
Advanced large-aperture deluxe model featuring Pyrex mirrors and enhanced aluminum optical coatings with 94% reflectivity for brightest images. Also formica/teflon bearings for buttery smooth movements, and oversized 4-vane fully adjustable secondary mirror support. Unique optical tube handles allow easy lifting of telescope tube.

Comes with high-quality 26mm Plössl eyepiece and now with your choice of focuser!

	A. 2" Low Profile	B. 1.25" Rack & Pinion	C. 2" Rack & Pinion	D. 2" Crayford	S&H
10"	#9913 **$749**	#9922 **$759**	#9919 **$808**	#9916 **$838**	(69.00)
12.5"	#9914 **$899**	#9923 **$909**	#9920 **$958**	#9917 **$988**	79.00)
16"	#9915 **$1,299**	#9924 **$1,309**	#9921 **$1,358**	#9918 **$1,388**	Add $75 crating charge; truck freight collect

Shown with optional finder scopes

Orion SkyView™ Equatorial Telescopes



SkyView™ 90mm Refractor

This fantastic large-aperture refractor telescope features a multi-coated f/11 achromatic objective lens for superb images. Especially suited to planetary, lunar, and stellar observation, its aperture is large enough to give spectacular views of star clusters and nebulas. Smooth rack-and-pinion 1.25" focuser, 90° prism diagonal, and **two** Kellner eyepieces, 25mm (40x) and 9mm (111x).

#9072 **$599** (28.30)

SkyView™ 4.5" Reflector

This all-new reflector is ideal for the beginning astronomer who wants the features of an equatorial mount, without compromising stability. The 114mm-diameter (4.5") precision optics are great for deep-space and planetary observation. Includes smooth rack-and-pinion 1.25" focuser and **two** Kellner eyepieces, 25mm (36x) and 9mm (100x). f/8 focal ratio.

#9071 **$399** (26.58)

SKYVIEW FEATURES

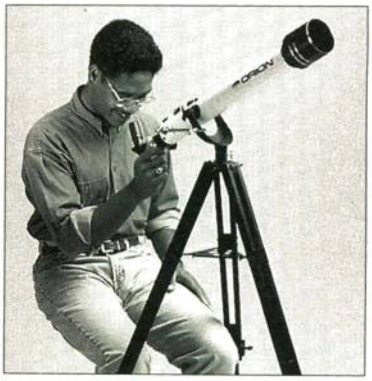
- Strong equatorial mount with worm-gear tracking controls.
- **Two** eyepieces, 25mm and 9mm Kellner, included.
- Durable **aluminum** optical tubes resist dents and rust.
- Oversized knob-style motion locks and cable controls.
- Strong adjustable aluminum tripod with eyepiece tray.
- Achromatic 6x30 finder scope with two-ring bracket.

New!

Electric Focuser for SkyViews

Enjoy smooth, jiggle-free focusing of your Orion SkyView 90mm Refractor or SkyView 4.5" Reflector, without touching the scope itself. Attaches quickly over focus knob. Compact two-directional hand controller. Clutch disengage button allows manual focusing at any time with motor in place. Runs on two AA batteries (not included). Motor also fits many Celestron scopes, including Premium 80, C4.5, and GP-C102.

#2363 **$39.95** (3.19)



Observer 60mm Refractor

Great for viewing Saturn's rings, lunar craters, and distant earthly scenes. Features an all-metal optical tube and altazimuth mount, precision prism-type diagonal and coated 25mm (28x) Kellner eyepiece, and hardwood tripod. Compare with models selling for much more! Standard model has 90° diagonal prism for stargazing; Terrestrial model includes 45° correct-image diagonal better suited for ground observation.

Standard Model
#9079 **$149** (7.27)

Terrestrial Model
#9088 **$199** (7.27)

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Eyepieces and Barlows

Orion 5-Element Ultrascopic™ Eyepieces

With Superb, High-Performance Ultra™ Multi-Coatings!

Ultrascopic eyepieces yield the highest contrast, greatest light transmission, and best overall image fidelity obtainable. With a superior 5-element design and Ultra™ Multi-Coatings on every surface, they outperform 4-element eyepiece designs. Wide 52° field of view. Removable contoured rubber eyeguard. The 5mm and 3.8mm feature advanced 7-element designs with surprisingly long eye relief. Guaranteed to knock your socks off!

Medium-High Power 5-Element 1.25"

20mm #8566, 15mm #8568, 10mm #8570, 7.5mm #8572 **$89 each** (3.45)

Wide-Field 5-Element 1.25"

25mm Ultrascopic	#8564	**$99** (3.45)
30mm Ultrascopic	#8562	**$119** (3.45)
35mm Ultrascopic	#8560	**$139** (3.45)

High-Power 7-Element Long Eye Relief 1.25"

5mm Ultrascopic	#8574	**$109** (3.45)
3.8mm Ultrascopic	#8576	**$109** (3.45)

Explorer™ Multi-Coated Eyepieces

Great performance at Orion's low direct-discount price. Internally blackened, threaded for filters (except 40mm .965").

.965" Kellner and Achromatic Huygenian
K 18mm #8584, K 25mm #8585, AH 40mm #8586 **$39.95 each** (2.98)

.965" Orthoscopic
5mm #8580, 7mm #8581, 9mm #8582, 12.5mm #8583 **$54.95 each** (2.98)

1.25" Kellner
6mm #8536, 9mm #8538, 12mm #8540, 18mm #8508, 25mm #8510, 40mm #8512 **$49.95 each** (2.98)

1.25" Orthoscopic
5mm #8500, 7mm #8502, 9mm #8504, 12.5mm #8506, 18mm #8524, 25mm #8526 **$59.95 each** (2.98)

Observer 2" Wide-Angle Eyepieces

Enjoy dazzling wide-field views of the cosmos for a very reasonable price. Multi-coated. Use with any 2" focuser or diagonal. Barrels are threaded for 2" filters.

32mm Erfle	#8492	**$109** (3.45)
50mm Plössl	#8490	**$99** (3.45)

UltraZoom™ 7–21mm

Owning an UltraZoom is like having a whole eyepiece collection in one ocular! Features a fully coated 7-element lens system and a 3-to-1 zoom ratio, from 7mm (65° apparent field) to 21mm (35°). 1.25" barrel.
#8556 **$179** (3.67)

✧ Sirius™

Quality Plössl 1.25" Eyepieces

Fantastic Fully Coated Eyepieces at an Incredibly Low Price!

You could pay nearly twice the price for "famous name" Plössl eyepieces, but why? Sirius Plössls are top-quality, 50° apparent-field (43° 40mm) eyepieces that yield extremely sharp images of impressively high contrast. Ideal for all types of telescopes. The classic 4-element Plössl design is renowned for its fantastic performance. The Sirius Plössl's fully-coated optics are mounted in black-anodized aluminum housings with chrome-plated brass barrels for durability and precision fit. Available in 1.25" barrels only.

7.5mm #8738, 10mm #8736, 12.5mm #8726, 17mm #8734, 20mm #8733, 26mm #8732 **$49.95 each** (3.45)

32mm #8728, 40mm #8730 **$59.95 each** (3.67)

Custom Field Case *(holds up to four eyepieces except for the 32 mm or 40mm)* #5911 **$12.95** (2.19)

Illuminated Reticle Eyepieces

Great for astrophoto guiding, polar alignment, and other uses. All models illuminated with a night-vision red LED.

12mm Kellner 1.25"
Double crossline reticle, fixed brightness. Plugs into power panel drive bases. #8482 **$79.95** (3.45)

12mm Kellner Wireless 1.25"
Same as #8482 except wireless. Needs two SR-44 batteries, not included. #8481 **$99** (3.45)

12.5mm Plössl Wireless 1.25"
With fully adjustable brightness control. Double crossline reticle. Batteries included. #8484 **$129** (3.45)

9mm Orthoscopic Wireless 1.25"
Bull's-eye within crosshairs, adjustable brightness. Needs two SR-44 batteries, not included. #8488 **$149** (3.67)

Orion Barlow Lenses

Double or even triple the power of your eyepieces, maximizing the versatility of your collection. Available in .965", 1.25", and 2" diameters.

Fully Baffled 2x Barlow
Multi-coated, with internal baffling to block transmission of stray light. Premium performance at a remarkable price.

.965" 2x Barlow	#8740	**$39.95** (2.98)
1.25" 2x Barlow	#8746	**$49.95** (2.98)
2" 2x Barlow	#8724	**$89.95** (3.95)

VariPower 2x–3x Barlow
Our most versatile barlow. Adjusts to any magnification between 2x and 3x. Fully multi-coated optics. 1.25" barrel. #8748 **$69.95** (3.45)

Shorty™ Barlows
About half the length of our regular barlows for added convenience. Magnifies 2x or 3x when positioned behind or in front of diagonal, respectively, on a refractor or Schmidt-Cassegrain. Works in all scopes, including those in which longer barlows won't work.

.965" Shorty Barlow	#8710	**$49.95** (2.98)
1.25" Shorty Barlow	#8711	**$49.95** (3.45)

Filters

Orion Light-Pollution Filters

Essential equipment for today's astronomer, Orion light-pollution filters enhance deep-sky views from light-polluted skies. Sophisticated multilayer technology absorbs offending wavelengths, for maximum contrast. Orion filters consistently outperform competing brands!

SkyGlow™ Broadband Filters

Rated the #1 broadband filter by *Sky & Telescope* (7/95): " I Found the Orion SkyGlow to be the most useful."

For slightly to moderately light-polluted areas.

.965" Broadband Filter fits .965" eyepieces. #5661 **$44.95** (2.98)

1.25" Broadband Filter fits1.25" eyepieces. #5660 **$69.95** (3.45)

2" Broadband Filter fits 2" eyepieces. #5659 **$109** (3.45)

SC Broadband Filter fits rear cell of Meade and Celestron Schmidt-Cassegrain scopes. #5658 **$89.95** (3.45)

UltraBlock™ Narrowband Filters

"The UltraBlock gave superior results." *Astronomy* (2/91)

For severely light-polluted areas and faint nebulas.

.965" UltraBlock Filter fits .965" eyepieces. #5655 **$79.95** (2.98)

1.25" UltraBlock Filter fits 1.25" eyepieces. #5654 **$99.95** (3.45)

2" UltraBlock Filter fits 2" eyepieces. #5657

SC UltraBlock Filter fits rear cell of Meade and Celestron Schmidt-Cassegrain scopes. #5656 **$149 each** (3.67)

Moon Filters

Cuts 87% of the light from the Moon, reducing glare to reveal more detail and help preserve night vision.

.965" #5664, 1.25" #5662 **$15.95** (2.43)

Glass Solar Filters

Full-aperture optical glass filters, for superb images and safe viewing of the Sun. Great for both visual and photographic use. Fits over front of telescope.

For 8" Schmidt-Cassegrains	#7713	**$129** (4.05)
For 10" Schmidt-Cassegrains	#7715	**$139** (4.05)
For 8" Deep Space Explorer	#7718	**$129** (4.05)
For 10" Deep Space Explorer	#7719	**$129** (4.05)

Many other sizes available. See our free catalog for details

Color Eyepiece Filters

Made from absolutely the highest-quality photo-grade optical glass, anti-reflection coated. Ideal for contrast-enhancing planetary and lunar observations and photography with any telescope. Black-anodized aluminum cell threads into any standard eyepieces, or into our universal camera adapters.

.965" Set of 4 #80A Blue, #58 Green, #25 Red, #15 Yellow. #5510

1.25" Starter Set of 4 #80A Blue, #58 Green, #25 Red, #15 Yellow. #5514

1.25" Expansion Set of 4 #21 Orange, #47 Violet, #11 Yellow-Green, #82A Pale Blue. #5516

1.25" Advanced Set of 4 #8 Yellow, #23A Light Red, #38A Deep Blue, #56 Light Green. #5570

$49.95 each (2.98)

2" Set of 4 Includes #80A Blue, #58 Green, #21 Orange, and #12 Yellow. #5513 **$99.95** (2.98)

Individual Filters
.965" and 1.25" **$14.95**, 2" from **$32.50**

Observing Aids

Orion FlexiShield™ Dew Caps

Fights moisture buildup. Flexible black material fits snugly around scope tube; Velcro fastener. Rolls up or flattens for convenient storage and travel. Models to fit most telescopes.

8" Celestron/Meade SC	#4200	**$44.95** (2.98)
9-1/4" Celestron SC	#4214	**$48.95** (2.98)
10" Meade SC	#4201	**$54.95** (2.98)

Other sizes available for scopes 3.5" to 14". See our free catalog for details.

Orion Dew Zapper™

Gently warms perimeter of corrector plate, eliminating dew buildup without "heat wave" disturbances.

8" Dew Zapper fits Meade & Celestron 8" SCs
DC #3503, **AC** #3504 **$47.95** (2.98)

10" Dew Zapper fits all Meade 10" SCs
DC #3506, **AC** #3508 **$54.95** (2.98)

11" Dew Zapper fits all Celestron 11" SCs
DC #3510, **AC** #3512 **$59.95** (2.98)

Eyepiece & Accessory Cases

With patented unbreakable latches, die-cut foam inserts. (Inside dimensions shown)

Small Case (shown) 11"x7"x3" #5951 **$19.95** (2.78)

Medium Case 12.5"x9"x5" #5952 **$27.95** (3.36)

Large Case 16"x11"x5" #5953 **$42.50** (5.19)

Observer's Chairs

Standard Model Adjustable-height center column and padded seat. #5935 **$34.95** (4.70)

Deluxe Model Built for professional musicians. Extra heavy-duty. #5934 **$98.50** (8.02)

Telescope Covers and Tote Bags

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All our scope totes and covers are made of rugged, water-resistant nylon, and are heavily stitched to last.

Soft Scope Cases

These heavily foam-padded carrying cases are real space-savers! Zipper access, with accessory pouch (SC models only) and strap handles.

For SkyView 90mm	#15146	**$98** (4.45)
For SkyView 4.5"	#15148	**$98** (4.45)
For Celestron C5 & Meade 2045D	#15142	**$109** (4.45)
For Celestron and Meade 8" (except LX200)	#15141	**$139** (4.98)
For Meade 8" LX200	#15144	**$149** (4.98)

Dobsonian Tote Bags

Holds Orion Deep Space Explorer tubes. May also fit some home-built Dobsonians. Nylon drawstring closure. Black nylon shoulder straps.

6" DSE Bag 10"x10"x60"	#15150	**$49.95** (3.41)
8" DSE Bag 12"x12"x62"	#15151	**$54.95** (3.41)
10" DSE Bag 14"x14"x68"	#15152	**$64.95** (3.54)

Tripod & Wedge Bags

Designed to hold Schmidt-Cassegrain tripods and wedges. Handy carrying straps.

Economy Tote and Storage Bag Inexpensive reinforced tote bag without padding. Zippered pocket, nylon drawstring. Length 4' 2", width 1' 5". #15095 **$34.95** (3.41)

Lightweight Tripod Bag Fits the Celestron lightweight tripod for C5 and C8+ telescopes (without the wedge). Zippered closure. Inside pocket. #15143 **$43.95** (3.26)

Field Tripod and Wedge Bag For Celestron or Meade standard tripod and wedge combinations (not Meade Superwedge or Celestron Ultima wedge). No need to remove the wedge from tripod. Length 4' 2", width 1' 10". #15096 **$79.95** (5.19)

Deluxe Tripod and Wedge Bag Fits Ultima tripod with wedge attached. #15140 **$109** (5.19)

Scope Caps for Deep Space Explorers

Water-resistant soft nylon cap, may also fit other comparably sized Newtonian tubes.

For 6" DSE	#15180	**$6.50** (2.19)
For 8" DSE	#15181	**$8.95** (2.19)
For 10" DSE	#15182	**$10.95** (2.19)
For 12.5" DSE	#15183	**$14.95** (2.19)
For 16" DSE	#15184	**$18.95** (2.19)

Scope Saver™ Telescope Covers

Water-resistant blue nylon hood protects your scope from the elements. Nylon drawstring closure with cord lock.

For Dobsonian Telescopes Covers entire tube and base. Great for keeping it covered while not in use, or during transport. Fits Standard or Premium Deep Space Explorers, Newtonian tube assemblies, or home-built telescopes.

6" Std. 9"x12"x54"	#15135	**$34.95** (2.43)
8" Std. 10"x14"x54"	#15136	**$39.95** (2.43)
10" Std. 12"x14"x55"	#15137	**$50.95** (2.43)
10" Prem. 12"x12"x64"	#15154	**$59.95** (4.98)
12.5" Prem. 17"x17"x74"	#15155	**$69.95** (3.54)
16" Prem. 20"x20"x84"	#15156	**$96.95** (4.45)

For SCs and Small Equatorial Telescopes
Fits over the optical tube either on or off the tripod.

8" SC Model Fits any Celestron or Meade 8" Schmidt-Cassegrain telescope. 10"x12"x34" #15130 **$33.95** (2.43)

10"–11" SC Model Fits Meade 10", Celestron Ultima 11" (not original C-11), and Celestron CG-11 telescopes. 14"x16"x44" #15131 **$39.95** (2.43)

4.5"–6" Model Fits 4.5" to 6" Newtonian reflectors, such as SkyView 4.5, Celestron 4.5, C6. 6"x22"x38" #15134 **$37.95** (2.43)

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Binoculars

Orion 50mm Vista™

A top-quality astronomical binocular, the Vista features BAK-4 prisms and fully multi-coated optics for high-fidelity images. Long 16mm eye relief and roll-back eyecups for eyeglass wearers. Weighs just 28 oz. Includes hard carrying case.

7x50 6.0° field of view	#9355	***$219*** (5.19)
10x50 5.3° field of view	#9353	***$219*** (5.19)

7x50 Adlerblick Binoculars

Incredible wide-field eyepiece design. Fully multi-coated. BAK-4 prisms make the 7x50 Adlerblick rival European brands selling for many times the price. 7° field of view, 26mm eye relief , 7.14mm exit pupil. Soft roll-down rubber eye-guards. Weighs 28 oz. Includes deluxe hard case, neck strap, and lens caps.

#9612 ***$299*** (5.28)

Orion 50mm Explorer™

High-performance, economical binoculars with BAK-4 prisms and multi-coatings. Great for both stargazing and daytime viewing. Rubber body coating for sure grip. Includes case, neck strap, and lens caps.

7x50	#9306	***$129*** (4.44)
10x50	#9308	***$129*** (4.44)

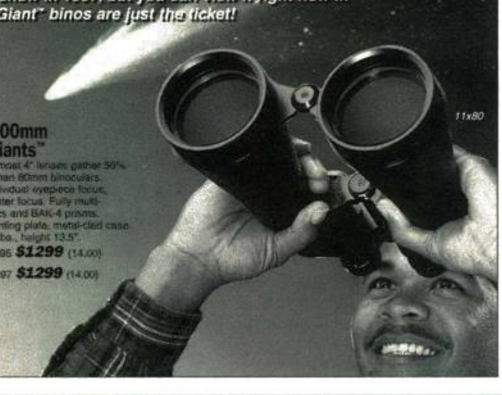
Orion 50mm UltraView™

The perfect binocular for eye- and sunglass wearers. Extra-long 23mm eye relief and unique pop-down eyepiece guard. Fully multi-coated optics for high light transmission and maximum contrast. BAK-4 prisms. Close focus 16'. Weighs 32 oz. Includes soft nylon case, eyepiece rain shield, and neck strap.

7x50	#9357	***$179*** (4.95)
10x50	#9351	***$179*** (4.95)

CATCH COMET HALE-BOPP!

Hale-Bopp promises to put on a spectacular show in 1997, but you can view it right now in binoculars. Our Little Giant™, Giant, or SuperGiant™ binos are just the ticket!



Orion 70mm Little Giants™

The standard for hand-holdable high-power astronomy binoculars. Fully multi-coated. Terrific brightness and edge sharpness! Weighs only 56 oz. Includes tripod mounting adapter and deluxe hard case.

10x70 #9501, **14x70** #9494 ***$369*** (6.97)

Orion 80mm Giant Binoculars

For jaw-dropping views of the heavens and Earth, our wide-aperture Giants can't be beat. Fully multi-coated optics and BAK-4 prisms provide fantastic contrast and edge sharpness. 20% more light transmission than "fully-coated." Includes deluxe hard case with handle and shoulder straps.

11x80 Brightest, widest field available. Ideal for deep-space observation under dark skies. Hand-holdable.
#9502 ***$469*** (8.05)

16x80 Excellent for astronomy and daytime observation. Tripod recommended.
#9496 ***$469*** (8.05)

20x80 Highest-power model, perfect for smaller deep-space objects and long-range daytime views. Tripod required.
#9498 ***$469*** (8.05)

Orion 100mm SuperGiants™

Gigantic, almost 4" lenses gather 50% more light than 80mm binoculars. 14x has individual eyepiece focus, 25x has center focus. Fully multi-coated optics and BAK-4 prisms. Tripod mounting plate, metal-clad case. Weight 7.5 lbs., height 13.5".

14x100	#9495	***$1299*** (14.00)
25x100	#9497	***$1299*** (14.00)

Quality Components

6x30 Achromatic Finder Scopes

6x30mm Straight
Includes 2-ring metal bracket, fits scopes 6"–12".
#13023 (white) ***$49.95*** (3.41)

6x30mm Right-Angle Prism for right-angle viewing. Includes bracket.
#13021 (white) ***$79.95*** (3.41)

Large-Aperture Finder Scopes

High-quality finders at very reasonable prices! Wider apertures for brighter views. Fully coated achromatic optics with adjustable focus. Precision crosshairs. White or black enameled metal tube. (Mounts sold separately.)

8x50mm Bright 6.25mm exit pupil.
#7090 (white) #7094 (black) ***$79.95*** (3.41)

8x50mm Illuminated Wireless illuminator with adjustable brightness.
#7092 (white) #7096 (black) ***$119*** (3.41)

9x60mm 44% more light grasp than 50mm models.
#7091 (white) #7095 (black) ***$119*** (3.41)

9x60mm Illuminated Wireless illuminator with adjustable brightness.
#7093 (white) #7097 (black) ***$159*** (3.41)

Low-Profile Helical Focusers

Economical yet precise focusing. Ideal for fast optical systems. Cast aluminum base with threaded, machined aluminum inner tube.

1.25" Helical Focusers	#13014	***$39.95*** (2.45)
2" Helical Focusers	#13016	***$59.95*** (2.98)

Rack-and-Pinion Focusers

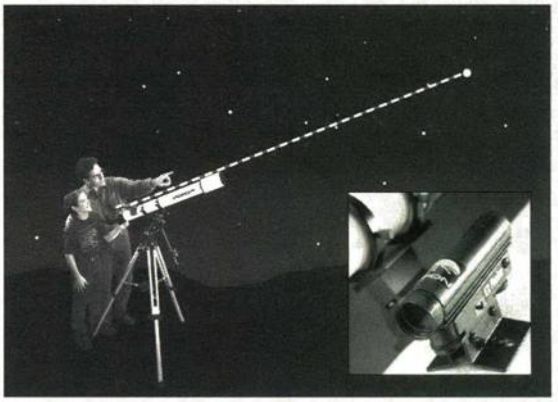
Finest in their class! Diagonal-cut plated brass racks, oversized knurled knobs, long-focus travel.

1.25"	#13007	***$69.95*** (2.98)
2" includes 1.25" adapter	#13003	***$119*** (3.95)

Dovetail Mounts for 50mm and 60mm Finder Scopes

Instantly install or remove your finder, without tools, without disturbing alignment! Black-anodized aluminum fits any scope 6" or larger including Celestron and Meade Schmidt-Cassegrains.

8x50mm Dovetail Mount	#5040	***$39.95*** (2.45)
9x60mm Dovetail Mount	#5041	***$47.95*** (2.98)
Extra Dovetail Mount Base	#5050	***$14.95*** (2.19)



EZ Finder™ Reflex Sight

This nifty device makes pointing a telescope almost as easy as pointing your finger. Keep both eyes open and look through EZ Finder, and you'll see the image of a red dot projected at infinity, showing exactly where the telescope is aimed in the sky.

Installs on any telescope in minutes. Wide 10° field of view, low and high brightness settings. Fits Meade and Celestron Schmidt-Cassegrain scopes in existing mounting holes; attaches easily to other scopes. Weighs just 2.5 oz.

#7075 ***$49.95*** (3.45)

Parabolic Primary Mirrors

Excellent hand-figured parabolic mirrors guaranteed to meet theoretical limits of resolution. Fine-polished, coated twice: with aluminum and silicon monoxide. Very competitively priced!

Standard Primary Mirrors
Fine soda-lime plate glass, 1:8 thickness ratio. Guaranteed ±1/8 wave. Sizes: 4.5" f/10, 6" f/8, 8" f/6, 10" f/4.5, 10" f/5.6, 12.5" f/4.8. *Call for pricing.*

Pyrex Low-Expansion Mirrors
Fine annealed Pyrex brand low-expansion glass, 1:6 thickness ratio. ±1/10 wave. Available with standard or 94% reflectivity, enhanced aluminum coatings. Sizes: 6" f/5, 6" f/8, 8" f/6, 10" f/4.5, 10" f/6, 12.5" f/6, 16" f/4.5. *Call for pricing.*

Elliptical Secondary Mirrors

Fine annealed Pyrex brand glass, aluminized and SiO overcoated. ±1/10 wave accuracy. Available with standard- or high-reflectivity enhanced aluminum coatings. Ten sizes from 0.75" to 4.00" minor axis. *Call for pricing.*

Astrositall-Zero Expansion Mirrors

Astrositall is a glass-ceramic material with an ultra-low coefficient of thermal expansion. Ideal for harsh environmental conditions. 1:7 thickness ratio. ±1/10 wave surface accuracy. Enhanced aluminum coatings.

Astrositall Parabolic Mirrors 6" f/8, 6" f/5, 8" f/6, 10" f/6
Astrositall Elliptical Flat Mirrors 1.30", 1.52", 1.83", 2.14". *Call for pricing.*

We also carry Sonotube Newtonian optical tubes, Dob altitude bearings, mirror cells, and other telescope components. See our catalog.

Orion Accessories

Lots More Accessories in Our 100-Page Color Catalog!

Orion accessories are absolutely guaranteed to be the finest quality available. Compare them side-by-side with higher-priced brands!

Universal Camera Adapters

For prime focus or eyepiece projection astrophotography.

.965"	#5268	***$27.95*** (2.98)
1.25"	#5264	***$29.95*** (2.98)
Hybrid 1.25"/.965"	#8782	***$29.95*** (2.98)

Variable-Power Camera Adapter

Allows variable projection distances during eyepiece projection photography. For 1.25"eyepiece holders.

#5262 ***$39.95*** (2.98)

Orion Slow-Motion Adapter

Attaches to your photo tripod pan head. Two slow-motion control knobs to make precision adjustments in altitude and azimuth. Very handy for tracking planets, the Moon, and constellations with refractor telescopes and small spotting scopes. Attaches with a standard 1/4-20 thread.

#7033 ***$39.95*** (2.19)

Tele-Extenders for Schmidt-Cassegrain Scopes

For high-powered photography with your Meade or Celestron 4", 8", 10", 11", 14" Schmidt-Cassegrain.

Standard Tele-Extender	#5125	***$29.95*** (2.98)
Variable Tele-Extender	#5127	***$39.95*** (2.98)

T-Adapters for SC and MAK

Threads to rear cell of telescope, requires T-ring for your camera model.

For SC	#5116	***$26.95*** (2.98)
For C90	#7115	***$34.95*** (2.98)

T-Rings for 35mm Cameras

Available for many different camera types; call toll-free or see our catalog for your particular model.

45° Correct-Image Diagonal Prisms

Ideal for all refractors and compound telescopes used for terrestrial viewing.

.965" Diagonal	#8791
1.25" Diagonal	#8790
Hybrid 1.25"/.965"	#8792

***$44.95* each** (3.45)

90° Star Diagonal Prisms

Orion's multi-coated diagonals are ideal for refractors and Schmidt-Cassegrains.

.965" Star Diagonal	#8761	***$29.95*** (2.98)
1.25" Star Diagonal	#8763	***$39.95*** (2.98)
Hybrid 1.25"/.965"	#14008	***$39.95*** (2.98)

Orion Ultra™ 2" Diagonals

2" Prism Diagonal Absolutely the finest-quality multi-coated 2" prism for highest light transmission.
For refractors #8770, **for Schmidt-Cassegrain** #8771
$219 (4.71)

2" Mirror Diagonal Affordable, high-quality first-surface optical flat star diagonal.
For Schmidt-Cassegrain #8772 ***$109*** (3.45)

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Electronic Finder & Sky Catalog

Let Sky Wizard do the work, while you relax and have fun observing!

- Find any celestial subject in 15 seconds!
- One minute set-up—no polar alignment or levelling.
- Observe hundreds of objects in just a few hours!
- For ANY telescope, with or without a motor drive. Even altazimuth or Dobsonian scopes!
- Digital display of celestial coordinates (RA and Dec).
- Built-in electronic sky catalog—find objects by their common catalog name, not their coordinates. Complete with object descriptions.
- Powered by a 9v battery or external 12v power supply (not included).

Sky Wizard Model 1
Database includes all 110 Messier objects, 225 double and variable stars, and the planets. Weighs just 4 oz.
#7801 ***$179*** (4.11)

Sky Wizard Model 2
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#7802 ***$249*** (4.44)

Sky Wizard Model 3
Gigantic 10,000 object database, including entire NGC and IC. Expanded object descriptions, RS-232 port.
#7803 ***$349*** (6.78)

Complete system requires Sky Wizard Model 1, 2, or 3, and a telescope installation package, sold separately.

Installation Packages

Includes two encoders, all required mounting hardware and brackets, connecting cables, and complete illustrated instructions. Installation packages are available for most telescope models. Call for details.

from $119–$326

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This handy, portable device connects the encoders on your telescope directly with your computer, allowing you to monitor your telescope's location with *TheSky* and *Deep Space* software programs (not included).

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PRODUCTS

Sky Cards

Australian astroimagers Luke Dodd and Gordon Garradd team up to create SkyCards, a series of seven cards that focus on some of the night sky's richest areas. One side of each 11" by 11", laminated card is anchored by a wide-angle color photo. The other side features six close-up photos of each region's best deep sky targets, along with position, brightness, and size information for all objects in the card's area of coverage. Currently the series profiles Crux, Scorpius, Canis Major, Sagittarius, Taurus and the Pleiades, and the Large and Small Magellanic Cloud areas. Other cards will follow in the future.

Luke Dodd, P.O. Box 114, Floreat Forum, Australia 6014; fax, 011-6165-788482; e-mail, 100250.3562@compuserve.com. SkyCards: $30 each card, plus $5 postage.

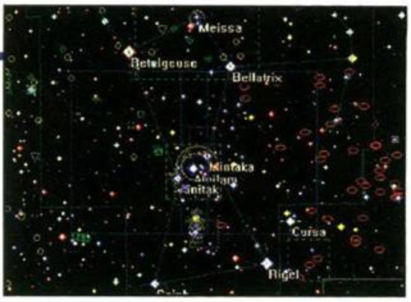
Lens-cleaning Pen

Celestron introduces Lenspen, a compact accessory designed to clean any lens surface. A retractable soft brush on one end of the pen removes loose particles of dirt. A soft cleaning pad on the other end, impregnated with a nonliquid carbon-based cleaning compound, wipes away smudges. The pad also stows away in the pen. Lenspen is seven inches long and comes with a clip that attaches to any pocket.

Celestron International, 2835 Columbia Street, Torrance, CA 90503; (310) 328-9560; fax, (310) 212-5835. Celestron Lenspen: $9.90.

ASTRO BYTES

HyperSky for Windows

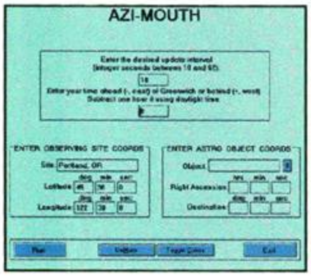


HyperSky, a computerized deep-sky star chart, is now available for Windows. The diskette version contains data files for 1,180 open clusters, 129 globular clusters, 1,455 planetary nebulae, 23,012 galaxies, and 46,178 stars down to 8th magnitude. Users can choose prebuilt configuration files to select field size and limiting magnitude for binocular, small telescope, or advanced deep-sky observing.

The optional CD-ROM data bank adds half a gigabyte of data, including 15 million stars from the Hubble Guide Star Catalog, 23 other star catalogs, 4 novae and supernovae lists, 18 catalogs of galaxies, 6 catalogs of galaxy clusters, the Strasbourg Galactic Planetary Nebulae catalog, 7 catalogs of open and globular clusters, 6 catalogs of nebulae, and catalogs of quasars and pulsars. This edition adds more than 30 new catalogs compared to previous HyperSky CD-ROM versions.

Willmann-Bell, Inc., P.O. Box 35025, Richmond, VA 23235, orders (800) 825-7827, (804) 320-7016, fax (804) 272-5920. Price: $49.95; optional CD-ROM database $49.95. Minimum requirements: IBM PC-compatible computer and Windows 3.1 or Windows 95. Optional databases require a CD-ROM drive.

Azi-Mouth and Julian



Azi-Mouth converts right ascension and declination into the altitude and azimuth needed for pointing a scope on an altazimuth mount. The program not only updates the position at regular intervals, it displays it in large characters visible from up to 50 feet away. The software also vocalizes the positions (hence the "Mouth" part of its name) so the observer can concentrate on moving the scope and not on the computer screen.

Azi-Mouth has a red-screen option for nighttime use and has some lists of bright star and deep-sky object positions. Users can add favorite objects to the lists. The Windows environment allows multiple copies of the program to run simultaneously so an observer can keep track of several objects. Julian accompanies Azi-Mouth so users can calculate the Julian date.

Ramshorn at Yamhill, 22571 NW Roosevelt Dr., Yamhill, OR 97148, (503) 662-3931, e-mail:ramshorn@ix.netcom.com. Price: $26.95. Minimum requirements: IBM PC-compatible computer, Windows 3.1, and a color monitor. Sound board and speakers are optional.

Linux for Astronomy

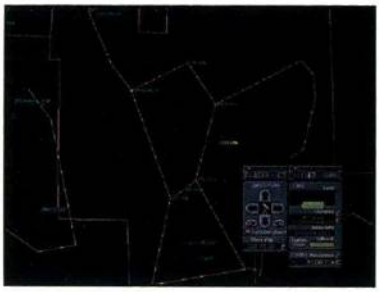
Linux for Astronomy
Volume
V1
1995

This CD-ROM contains professional data processing packages for astronomy such as AIPS, IRAF, MIDAS, NEMO, SAOIMAGE, and StarBase, as well as some Windows-based software for viewing images. It also includes the httpd and Viola for serving to and accessing from the Web. For more information, visit the Web site at http://www.earthlink.net/~rfactory/lfa.html

The Random Factory, 2217 E. Copper St., Tucson, AZ 85719, (520) 327-1687, fax (520) 327-3381, e-mail rfactory@earthlink.net. Price: $35; annual subscription of 2 issues: $55. Minimum requirements: Linux 1.2 and a CD-ROM drive.

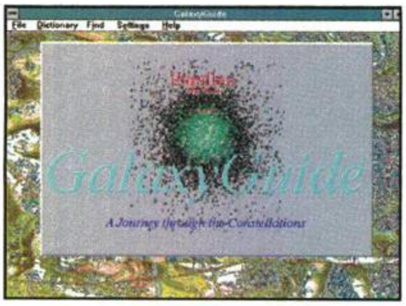
Product information is as provided by the developer. Software developers may send new programs and upgrades to AstroBytes, ASTRONOMY Magazine, P.O. Box 1612, Waukesha, WI 53187-1612 or e-mail bytes@astronomy.com. Check out ASTRONOMY's home page at http://www.kalmbach.com/astro/astronomy.html

Redshift 2.0



This new version of the Redshift planetarium program enables users to view planets, comets, asteroids, 250,000 stars, and 40,000 deep-sky objects. The program can display 3D images of the planets and views from the planet's or satellite's surface. The multimedia presentation also presents more than 700 images of planets and deep-sky objects, 11 movies of space missions, and 10 guided tours of space. Hypertext links allow users to look up words in Penguin's Dictionary of Astronomy, included on the disk. Maps of Earth, Venus, Mars, and the Moon pinpoint landing sites and geological features.

Maris Multimedia, 100 Smith Ranch Road, Suite 301, San Rafael, CA 94903, (415) 492-2819. Price: $49.95. Minimum requirements — PC: 80386SX-based computer, VGA display, 8 MB of memory, double speed CD-ROM drive, mouse, and Windows 3.1 or Windows 95; Macintosh: LCII, double speed CD-ROM drive, System 7.X, 8MB of memory, color monitor, and QuickTime 2.0. The CD-ROM contains both versions of the program.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GalaxyGuide

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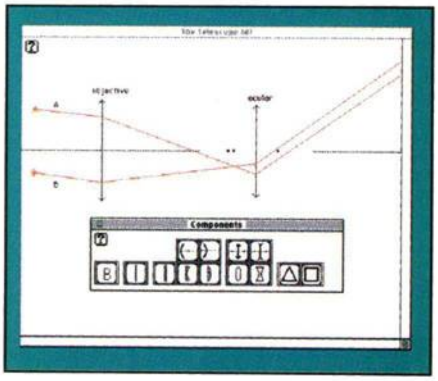
Parallax MultiMedia, 1233 Saddle Court, Auburn, CA 95603, (800) 884-0225, fax (916) 887-8729, e-mail parallax@aol.com. Price: $49.95. Minimum requirements: 25 MHz 80486-based computer, 9 MB of free hard disk space, 8 MB of memory, CD-ROM drive and Windows 3.1 or Windows 95.

Ray

This optical ray-tracing program provides an array of tools for creating and positioning simple lenses, mirrors, and prisms. Ray includes more than 100 activities for learning how optics work. The menus and tool windows make designing an optical system easy. Users can simulate the paths of multiple rays and colored rays through an optic or optical instruments such as binoculars or telescopes.

Physics Academic Software, Box 8202, North Carolina State University, Raleigh, NC 27695-8202, (800) 955-8275, fax (919) 515-2682, e-mail pas@aip.org, http://www.aip.org/pas/pashome.html Price: $69.95. Minimum requirements: Macintosh Plus and System 6.X.



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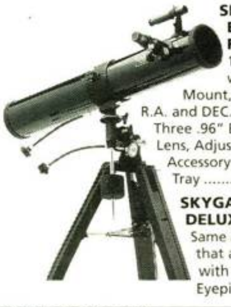

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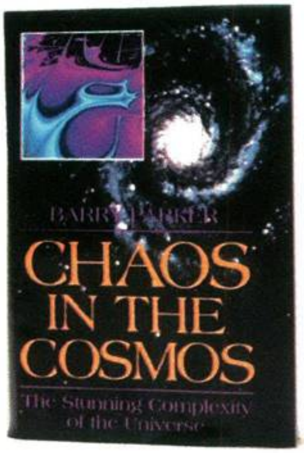
The Death of Determinism

by Lee Vande Visse

Chaos in the Cosmos: The Stunning Complexity of the Universe

Barry Parker, (Plenum Press, 1996), ISBN 0-306-45261-8, 300 pages, hardcover, $28.95.



Over the last 30 years, a discipline within mathematics has evolved, with stunning implications for physics and cosmology. This field, popularly known as chaos theory, is currently rewriting much of what we have assumed to be hardened fact.

What is chaos? Everyone has an impression of what the word means, but scientifically speaking, chaos is more than random behavior, lack of control, or complete disorder. Chaos basically means that small uncertainties in the initial conditions of a system quickly add up to enormous differences in future outcomes. For example, an uncertainty in the position of Pluto of a mere one centimeter will put Earth on the opposite side of its orbit 100 million years later. By applying chaos theory to the entire universe, scientists are redefining cosmology.

In *Chaos in the Cosmos*, Barry Parker, an Idaho State University astronomer, lays an important foundation by presenting the historical perspective. He examines the work of Newton, Maxwell, Boltzmann, and others that eventually led to the explosive resurgence of interest in chaos theory. Scientists once considered the universe to be completely deterministic. If one had enough information, one could theoretically determine all the past and future motions and interactions of all particles within the universe. Determinism was comfortable and predictable.

But as early as the 1800s, determinism was finding difficulty coping with complex systems. Significant to astronomy was the problem of calculating the exact future positions of three or more bodies orbiting a common center of mass. This classical problem defied solution using simplistic approaches. Parker revisits this problem throughout the book.

In more recent times, astronomers have found chaos within our own solar system in the rings of Saturn, the rotation of Saturn's odd little moon Hyperion, and the placement of the asteroids.

The application of chaos theory to cosmology is extremely important and constitutes the major portion of Parker's book. He investigates the effect of chaos on the large-scale structure of the universe and its application in explaining the uneven distribution of matter.

At this point Parker makes his most interesting observations. Developments in chaos theory have coincided with investigations into grand unified theories, which are attempts to link all of nature's disparate forces into a single, all-encompassing "theory of everything." Because chaotic systems defy predictability, chaos forbids us from knowing everything. When linked with the Heisenberg uncertainty principle in quantum mechanics, chaos theory, at least for the present, locks the door to a theory of everything. Against Einstein's wishes, chaos again reintroduces the likelihood that God does indeed play dice with the universe.

Chaos in the Cosmos presents an up-to-date discussion of chaos and the various theories and laws surrounding it. Parker has produced a book that is fun to read and that doesn't resort to mathematical formulae. Parker never deviates into associated fields without adding to the purpose of the book. *Chaos in the Cosmos* is definitely a worthwhile investment that will help you better understand the mechanics of the universe.

Lee Vande Visse (lvandevisse@kalmbach.com) produces many of the beautiful illustrations that appear in ASTRONOMY.

Other Books

Alvan Clark & Sons: Artists in Optics

Deborah Jean Warner and Robert B. Ariail, (Willmann-Bell, 1996), ISBN 0-943396-46-8, 298 pages, hardcover, $24.95.

Literally years in revision, the second edition of *Alvan Clark & Sons: Artists in Optics* is just about a complete rewrite of the 120-page 1968 first edition, now long out of print. The new edition is divided into several sections. The first details the Clark family's beginnings. The next two sections describe all the known Clark instruments, along with all their past and present owners. The fourth section explains why so many individuals and institutions wanted to obtain expensive Clark instruments. The fifth section describes various smaller telescopes, mountings, and engravings. The final section has little to do with telescopes, it lists a vastly expanded inventory of known Alvan Clark portrait paintings and drawings (Clark was an outstanding painter as well as telescope maker).

The book is extremely well documented, and uses extensive footnotes throughout. The authors acknowledge the help of several antique telescope buffs in the preparation of this book. For those interested in antique telescopes, this book is destined to become the source authority on 19th century telescopes. —*Gregory Gonia*

Telescopes and Techniques: An Introduction to Practical Astronomy

Christopher Robert Kitchin, (Springer-Verlag, 1995), ISBN 3-540-19898-9, paperback, 204 pages, $24.95.

This book, the first volume of Springer-Verlag's Practical Astronomy Series, explores basic techniques involved in using a telescope and

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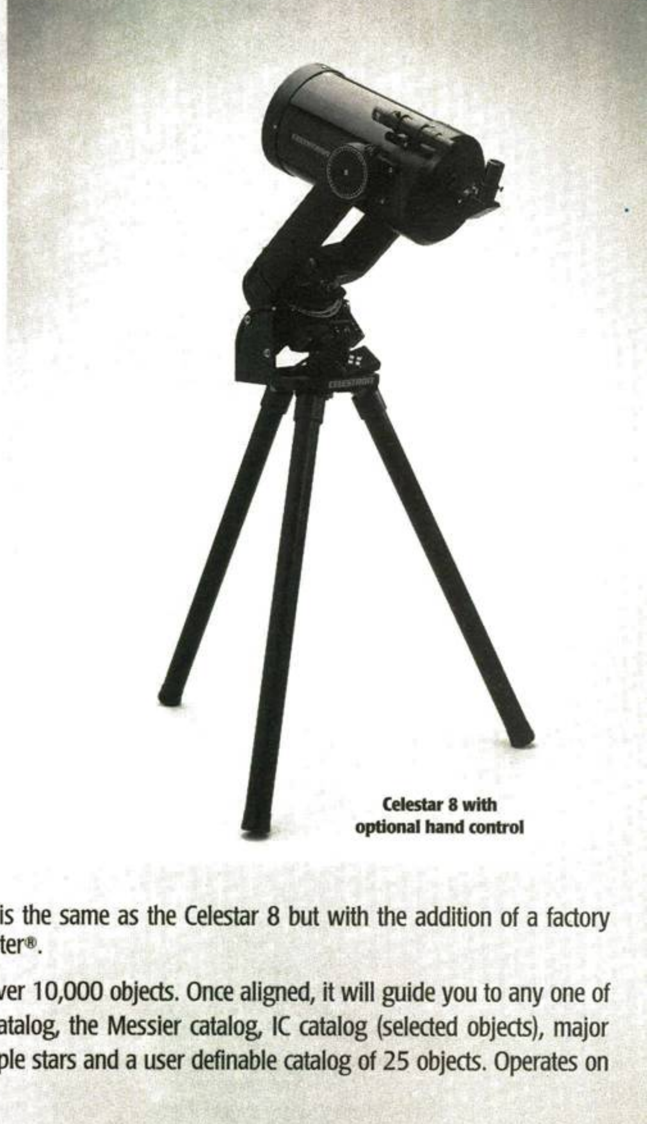
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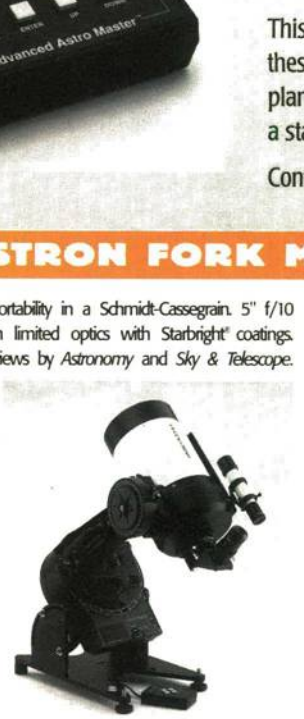

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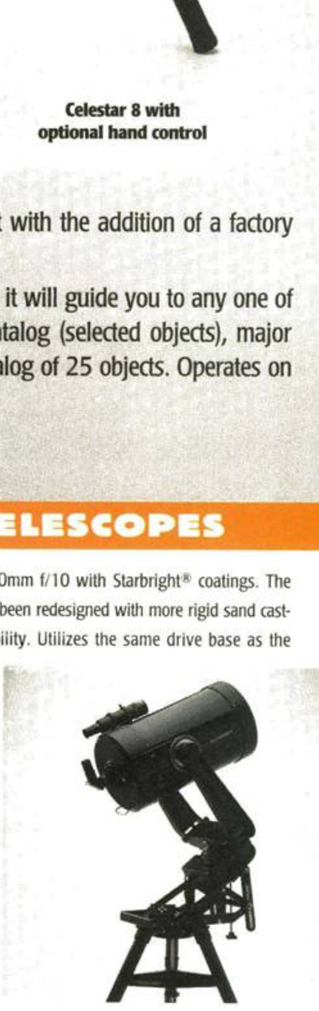

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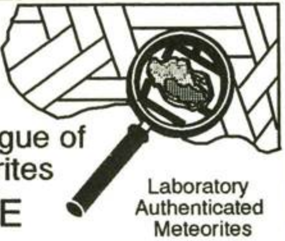

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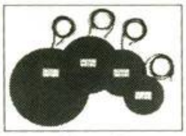

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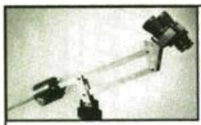

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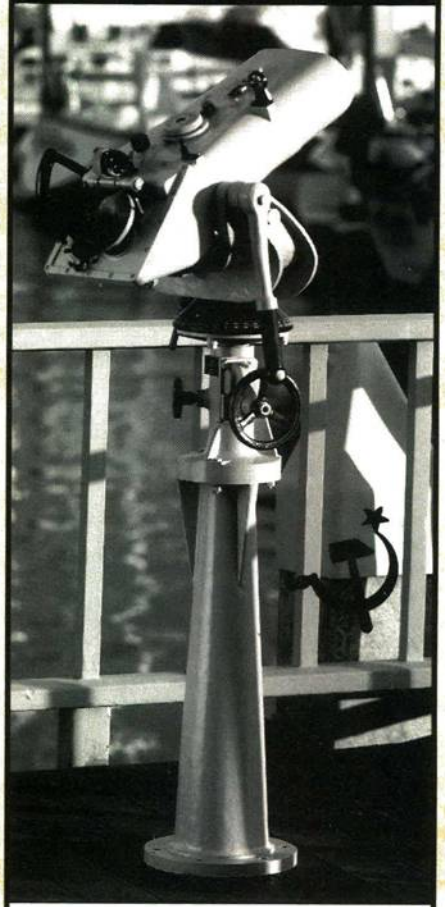

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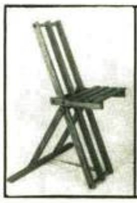

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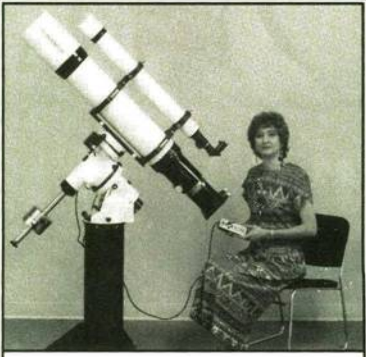

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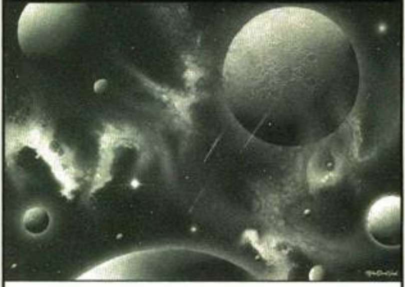

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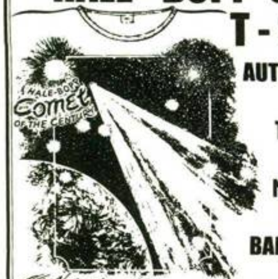

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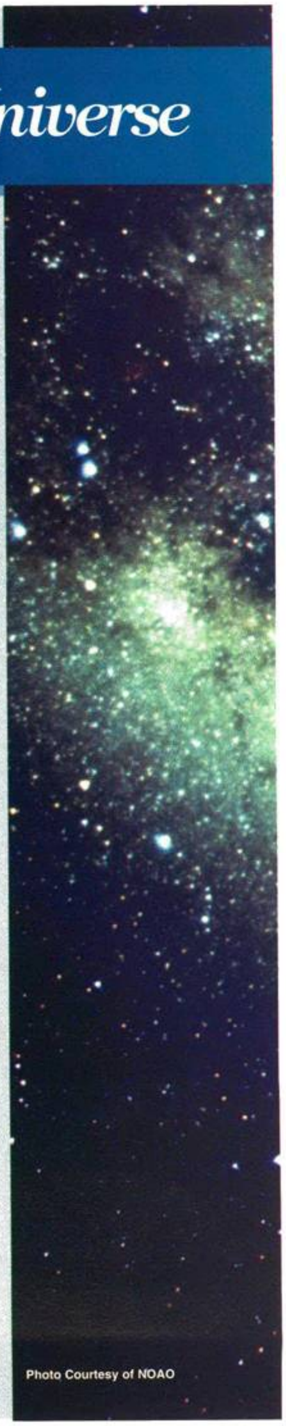

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SpaceWeek Celebration, National Air and Space Museum, Washington, D.C. Special weekend activities for families. Contact the National Air and Space Museum, (202) 357-1552.

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2nd Annual Northern Prairie Star Fest, Deneb Observatory, Scarles, North Dakota. Day trips and presentations scheduled, along with barbeque at farm site. Contact by writing John Leppert, Deneb Observatory, RR 1, Box 25, Scarles, ND 58372-9618, (701) 697-5225, http://73424.3533@compuserve.com.

July 20-26
20th International Congress of History of Science, Montpellier, France. Sponsored by the University of Montpellier Planetarium. Contact Dr. Jean Michel Faidit, The University of Montpellier, B. P. 1088, 34007 Montpellier, France.

July 27-31
The Asimov Seminar, White Eagle Conference Center, Hamilton, New York. Contact Doug Loss, The Asimov Seminars, P.O. Box 54, Rensselaerville, NY 12147-0054, (717) 389-4797, loss@husky.bloomu.edu.

July 29-August 17
International Astronomical Youth Camp, Coucouron, France. Sponsored by the International Astronomical Youth Camp. Open to all English-speaking youths ages 16-24. For detailed information and application form contact IWA e.V., Gwendolyn Meeus, Schapenstraat 11, 3000 Leuven, Belgium.

Continued on page 109

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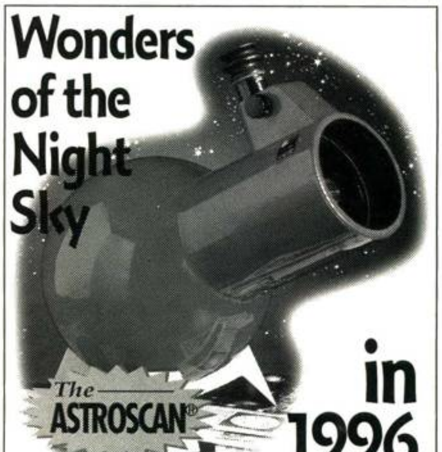

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MEETINGS & EVENTS

Continued from page 105

August 7
World Decennial Galaxy Party,
Rock Hill, South Carolina. Sponsored by the Galactic Society International. Contact GSI, Box 326, Rock Hill, SC 29731, (803) 328-0705.

August 9-11
Southern Idaho Regional Star Party,
Bruneau Sand Dunes State Park, Idaho. Sponsored by the Boise Astronomical Society. Contact Sam Johnson, (208) 939-2095, bas@micron.net.

August 9-11
Stellafane Convention,
Breezy Hill, Springfield, Vermont. Sponsored by Springfield Telescope Makers, Inc. Contact Stellafane Convention, P.O. Box 50, Belmont, MA 02178, http://stellafane.com/~stell/stelfane.htm.

August 9-18
5th Annual Summer Star Party and Family Camping Vacation,
Shady Pines Campground, 547 Loop Rd., Savoy, MA 01256. Sponsored by the Rockland (NY) Astronomy Club. Contact Don Urban, 73 Haring St., Closter, NJ 07624-1709, (201) 768-6575, durban1@aol.com.

August 10-17
3rd Annual Nebraska Star Party,
Merritt Reservoir, 27 miles south of Valentine, Nebraska. Sponsored by the Prairie Astronomy Club, Inc. Contact Tom Miller, 3400 N. 102 Street, Lincoln, NE 68527, (402) 466-4170.

August 14-18
Mt. Kobau Star Party,
Near Osoyoos, British Columbia, Canada. Sponsored by the Mt. Kobau Astronomical Society. Contact Ann Murphy, MKAS, P.O. Box 20119 TCM, Kelowna, BC, V1Y 9H2, Canada, (604) 764-8478. □

Please submit club announcements four months in advance to Meetings and Events, ASTRONOMY, P.O. Box 1612, Waukesha, WI 53187-1612, or tconley@astronomy.com.

RESOURCES & PHOTOFACTS

Plunge into the Lagoon (page 82)

"The H II Regions of Messier 8" by Beverly T. Lynds and Earl J. O'Neil, Jr. (*Astrophysical Journal*, **263**:130, Dec. 1, 1982). Includes detailed analysis of the Lagoon's famous dust.

OK, Where are They? (page 36)

Extraterrestrials: Where Are They? 2nd edition, edited by Ben Zuckerman and Michael Hart, (Cambridge University Press, 1995). The ET skeptic's Bible. □

---

p.74, top: Chris Schur, March 22, 5.5-inch f/1.65 Schmidt camera on hypered 2415 for six minutes; **right:** Tom Stafford, March 21, 300mm f/4 for 20 minutes on hypered Konica 400; **p. 75, top:** Gordon Garradd, March 22.6 UT, 16mm f/3.5 for 15 minutes on hypered Fujicolor Super HGV 400; **bottom:** Jason Ware, March 22, 6-inch f/9 refractor for 30 minutes on hypered Fuji HG400; **p. 76, top:** Tom Martinez, March 25, 30-inch f/5 for eight seconds on Fujicolor; **(drawing):** Tom Johnston, 13.1-inch f/4.5 at 78x on March 26; **p. 77, top two photos:** James De Buizer and James Radomski, Univ. of Fla., March 25, Photometrics Star 1 CCD camera on a 135mm lens for five minutes; **p. 78, top:** Jerry Schad, March 25, 24mm f/1.4 on Ektachrome P1600 for 3.5 minutes; **right:** Gerald Rhemann, March 21, 5-inch f/1.65 Schmidt camera on hypered 2415 for 14 minutes; **p. 79, top:** March Raddick, March 23, 24mm f/2.8 on Fujichrome 1600 for two minutes; **bottom:** Bob and Janice Fera, March 23, 200mm f/4 on hypered Fuji HG400 for 15 minutes; **p. 80, top left:** Scott Squires, March 27, 10mm f/4 on Fuji 400 SGP for 10 minutes; **top right:** Siegfried Manietta, March 24, two 10-minute exposures through an 80mm f/2.8 on hypered Fujicolor HG 400 120-format film; **bottom:** Richard Berry, March 21, Cookbook 245 CCD camera through a 4-inch f/5 Genesis refractor; **p. 81, top:** Ernest Sangraw, April 10, 300mm f/4 for eight minutes of Agfa Provira 1600; **bottom:** March Raddick, March 23, 24mm f/2.8 for two minutes on T-Max 3200 film.

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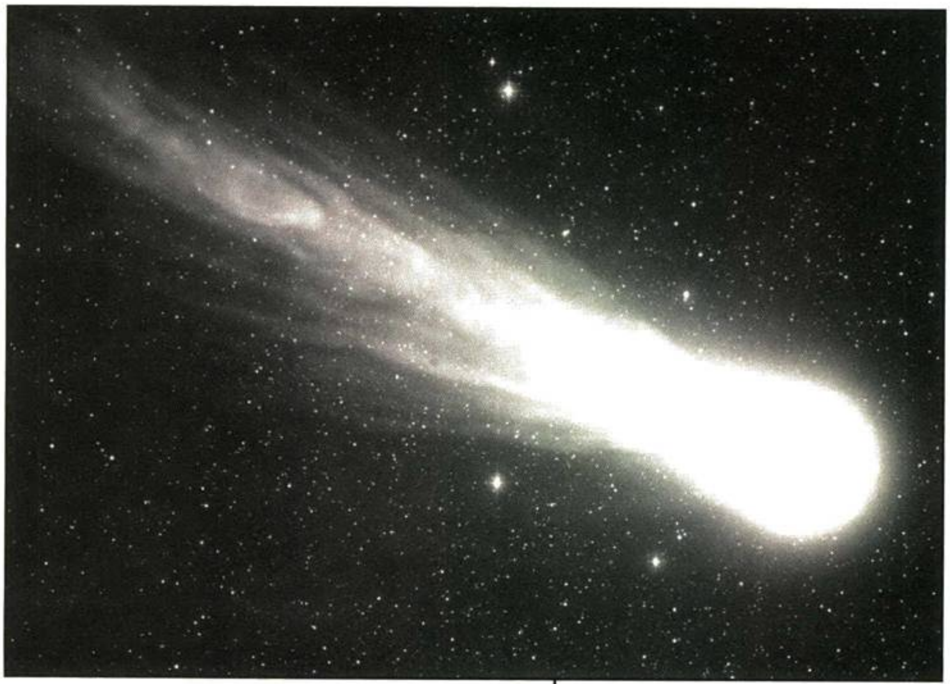
Reflections on the "Comet of the Decade"

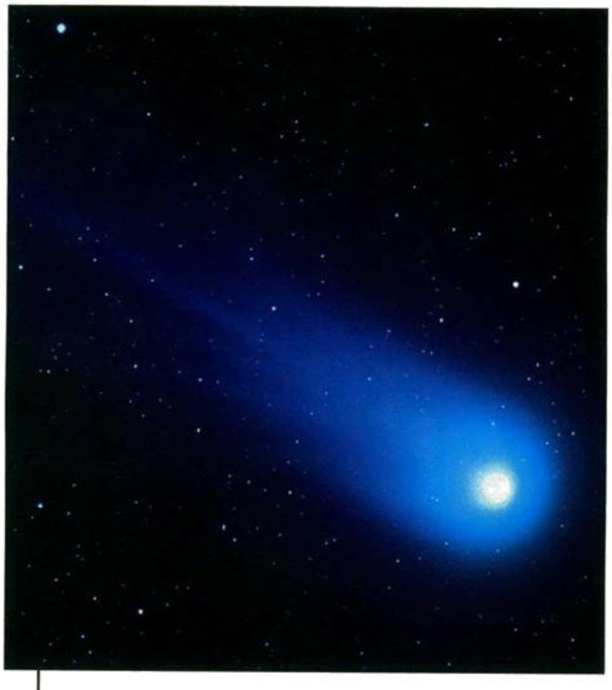
It was an exhilarating month for backyard astronomers. March 1996 brought the most spectacular comet since West in 1976 soared into view as Comet Hyakutake (1996B$_2$) sped past Earth at a distance of just 15 million kilometers at its closest approach. On its way toward perihelion, the comet also brightened in May but remained near the horizon in twilight. Placed at its best during March, however, Hyakutake peaked in brightness on March 25 at magnitude –0.5. When observed from a dark suburban site, the comet's tail stretched across 50°, from the coma near Polaris to beyond Coma Berenices. From really dark skies, tail lengths of 100° were reported. Moreover, because the comet passed so close to Earth, its image scale was magnificent. With a scale of 75 km/arcsecond, observers could see small features in the coma.

Discovered on January 30 by Yuji Hyakutake, the comet brightened rapidly throughout February, reaching naked-eye brightness by March 1. Richard Didick of Rehoboth, Massachusetts, described the comet on that date: "The coma appears fan shaped.



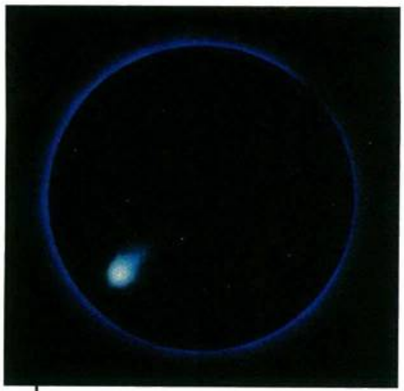
Rays and Kinks in Comet Hyakutake's Tail

by Chris Schur
(5.5-inch f/1.65 Schmidt camera, hypersensitized Tech Pan film, 6-minute exposure taken March 22, 1996)



The Comet's Delicate Ion Tail

by Ted Hodgkinson
(8-inch f/1.5 Schmidt camera, Sensia 100 film, 5-minute exposure taken March 23/24, 1996)



Hyakutake Seen in Binoculars

by Edwin Faughn
(11x80 binoculars, sketch made March 20, 1996)

A condensed nuclear region some 30" across lies at the eastern edge of a strongly condensed central brightening. The outer coma appears very faint." Didick was using a 10-inch reflector at 49x.

"I couldn't believe my eyes," says Artie Kunhardt of Brooklyn, New York. "The comet was just visible to the unaided eye on March 13, and was beautiful in a 13-inch reflector. By the 17th the comet was brighter — how it could go from 5th magnitude to magnitude 3.5 in four days was fantastic. I've seen Comet Halley and Comet Levy, but this one knocks your socks off!"

The real excitement came as the comet erupted in brightness during the last days of March. On the 22nd Tim Printy, Tom Clark, and others from the Local Group in Bradenton, Florida, hauled out Clark's 36-inch scope and viewed the comet. "In the big scope a bright jet extended from the nucleus in the same direction as the ion tail," says Printy. "The details in the center of the coma were not sharply defined, as the inner coma surrounding the comet's center seemed blurry. This comet was definitely better than IRAS-Araki-Alcock in 1983 and rivaled Comet West in 1976 for its spectacular displays." ☐

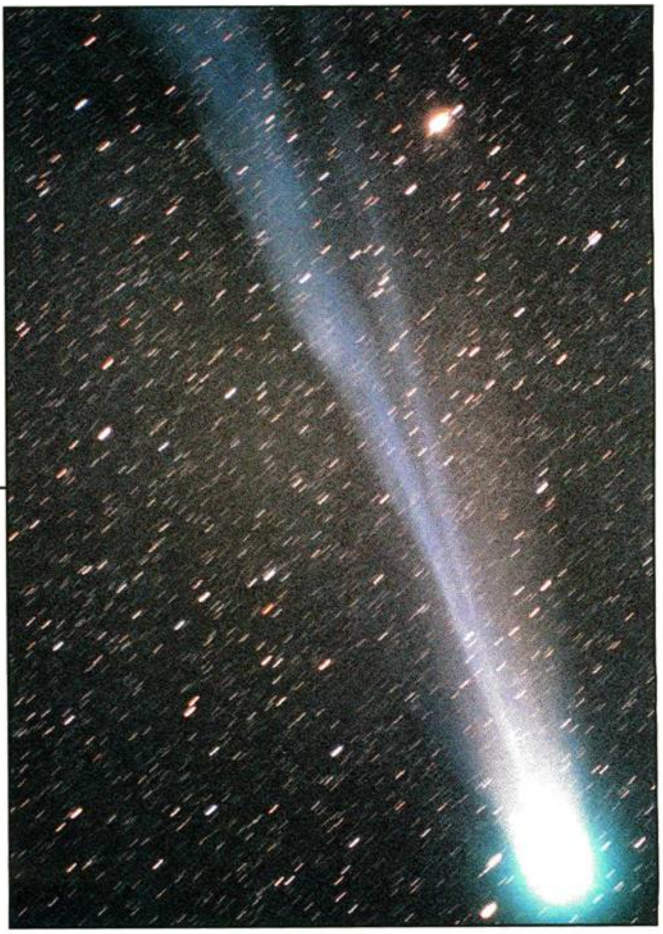
ASTRONOMY wants to hear about your observations of the sky. Send reports, sketches, photographs, and disks to David J. Eicher, Reader Reports Editor, ASTRONOMY, P.O. Box 1612, Waukesha, WI 53187–1612. Please label each photo with photo data, name, address, and social security number. You may send written reports and images via the Internet to: rreports@astronomy.com

Comet Over the Treetops

by Jerry Schad (85mm lens at f/2, Ektachrome P1600 film, 90-second exposure taken March 26, 1996)

Hyakutake Spills Out of the Dipper

by Dean Easton (28mm lens at f/4, hypersensitized Tech Pan film, 11-minute exposure taken March 27, 1996)



The Comet's Kinky Tail

by Tim Printy (135mm lens at f/2.8, Fuji 800G film, 16-minute exposure taken March 24, 1996)

Comet Hyakutake Hangs Over Aurorae

by Alan Dyer (16mm lens at f/4, ISO 1600 film at ISO 800, 6-minute exposure taken March 25, 1996)

Hyakutake Approaches the Pole

by Tim Rainey (50mm lens at f/2, 100 ISO film, 4-minute exposure taken March 26, 1996)

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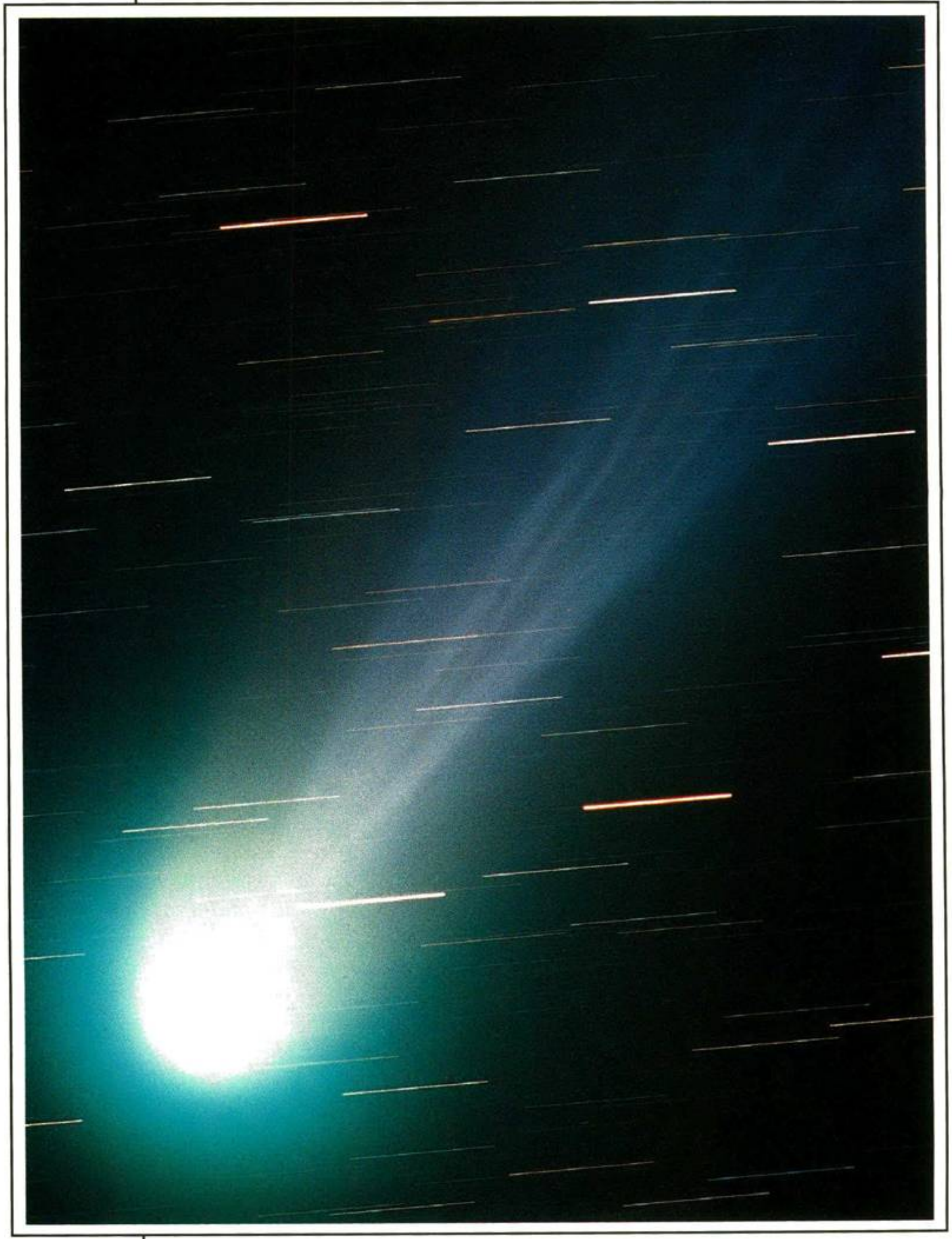

Parallel Streamers in Hyakutake's Tail

by David Churchill
(4-inch f/5.4 refractor, hypersensitized Fuji 800G film, 30-minute exposure taken March 23, 1996)

At the height of its brightness, Comet Hyakutake shows a brilliant coma, bluish-green as recorded in this image, and a broad cone of dust trailing away from the Sun. The more sharply defined gas tail appears lavender in color and appears to contain at least seven separate, parallel streamers that bend slightly a degree or so away from the coma.

The question that now looms large: will Hale-Bopp surpass Hyakutake in brightness and detail or even measure up?

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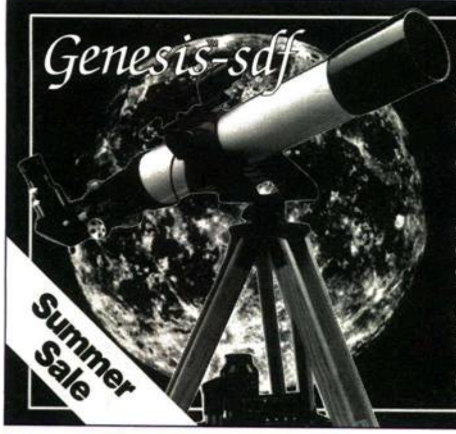

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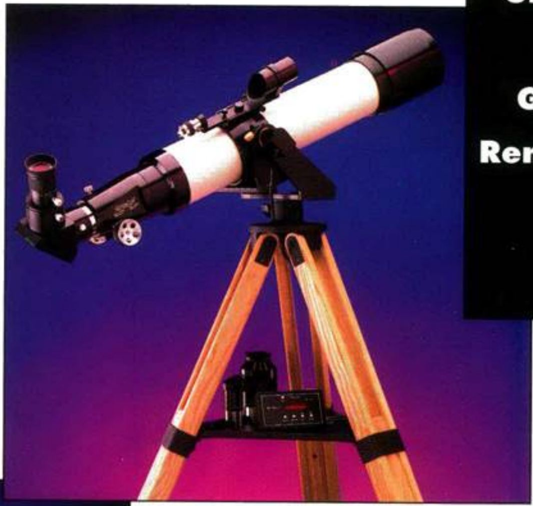

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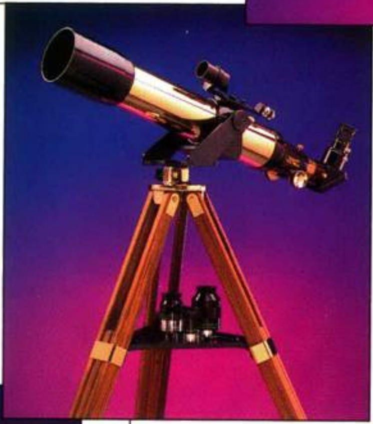

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Celestron® CG-$9^1/_4$

The first truly new size in Schmidt-Cassegrain telescopes in over 20 years!

The **CG-$9^1/_4$** introduces a **new** and **unique** large aperture Schmidt-Cassegrain telescope. It provides a 34% increase in light gathering power over 8" telescopes. It is a 2350mm focal length telescope at f/10.

The CG-$9^1/_4$ combines the unequaled optical excellence of the **Celestron $9^1/_4$"** Schmidt-Cassegrain with a superb German equatorial mount built for **Celestron** by Losmandy. This combination was built for the more serious astronomer who wants the maximum in rigidity.

The all-machined equatorial mount is a work of art. Both axes are driven by a 2.8" diameter, 180-tooth worm gear.

The R.A. and DEC assemblies incorporate two thrust bearings each. These axes are preloaded for zero play and variable friction clutched by a single knob. The $3^1/_2$" diameter laser engraved precision setting circles are readable to $^1/_4$ degree in DEC and four minutes in R.A. The R.A. circle is direct reading indexed to the R.A. gear motion. All these technical features deliver the smoothness, refinement, controllability and precision that you've always wanted in a fine mount.

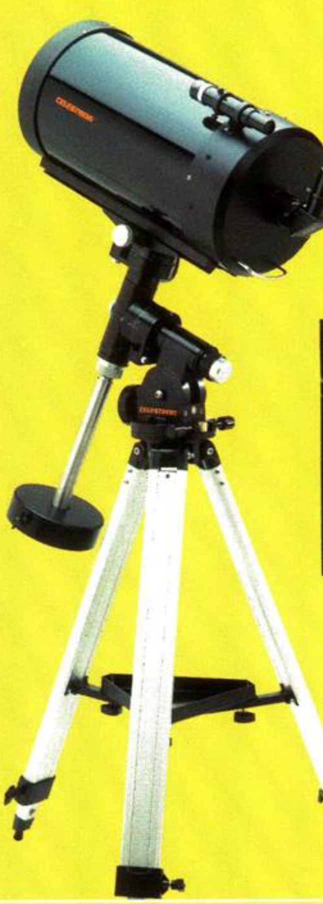
The CG-$9^1/_4$ dual axis DC electronics are state-of-the-art. Four tracking rates are available: sidereal, King, lunar and solar. It has four setting rates of 4x, 8x, 16x and 32x. Also it has three photo guide rates of ±30%, ±50% and 2x. The electronics have full feature PEC (Periodic Error Correction) built-in. TVC (Time Variable Constant) built-in is a user programmable declination backlash compensation for instantaneous tracking response. *Sky & Telescope* said, "the drive is so accurate that tracking was superb whether or not the electronic PEC feature was switched on."

The equatorial head weighs 21 lbs. without counterweight bar and is the heaviest individual component of this portable telescope. Total weight is 53 lbs.

The mount has an optional polar alignment scope available which works in both hemispheres. The latitude range is 0° to 64°.

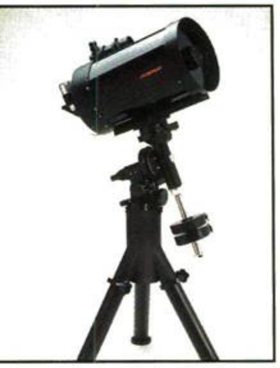
With the addition of the optional Advanced Astro Master®, you have a computerized telescope.

Standard accessories included are: 6x30 Finderscope, Star Diagonal – $1^1/_4$", and a multi-coated 26mm Plössl Eyepiece – $1^1/_4$" (90x). Starbright® coatings are included.



Comes standard with a unique focusing micrometer for ultra precise focusing for CCD imaging or astrophotography.

CELESTRON GERMAN MOUNT SCHMIDT-CASSEGRAIN TELESCOPES:



CG-11–An 11" (279mm) telescope with a focal length of 2800mm (f/10). It provides a significant 21% increase in light gathering power over 10" telescopes and 89% more than 8" telescopes.

It has a larger and heavier duty equatorial head than the CG-$9^1/_4$. Both axes are driven by a 5.6" diameter, 360-tooth worm gear.

Electronics are similar to the CG-$9^1/_4$.

The equatorial head weighs 31 lbs. and is the heaviest individual component of this portable telescope. Range 12° to 64°.

The rugged aluminum adjustable height tripod has 3" diameter legs, is 48" long and weighs 20 lbs.

Standard accessories include a 7x50 Finderscope, Star Diagonal – $1^1/_4$", Visual Back – $1^1/_4$" and a multi-coated 26mm Plössl Eyepiece – $1^1/_4$" (108x).

CG-14 – A 14" (356mm) telescope. It has a focal length of 3910mm and a focal ratio of f/11.

The German equatorial mount is the same as supplied with the CG-11 telescope but with additional counterweights.

This large aperture professional-type instrument is portable enough to easily transport for serious astronomical work. Experience incredible scientific research optical performance and awesome views.

The large aperture of the 14" has 306% more light gathering power than an 8" telescope and 96% more than a 10" telescope. Lunar and planetary detail is breathtaking. The tremendous aperture and superb optics combine for thrilling deep-sky observing of diffuse and planetary nebulae, open and globular star clusters, galaxies and binary stars.

Many of the finest amateur astrophotographs have been taken using the C14.

Standard accessories include a 7x50 Finderscope, Star Diagonal – 2" (with a $1^1/_4$" adapter) and a 26mm multi-coated Plössl Eyepiece – $1^1/_4$" (150x).

GP-C8 – This 8" (203mm) f/10 telescope comes with the Great Polaris mount.

Whether you are looking for a superior first telescope with a traditional German equatorial mount or want to move up to a larger aperture telescope, consider the GP-C8.

Both axes have precision 144-tooth lapped worm gears for very smooth motion. The adjustable height, very rigid wood tripod has excellent vibration dampening characteristics and has a handy accessory tray.

The GP mount has a built-in illuminated polar alignment scope for fast polar alignment.

The optional Polaris drive controller – a dual-axis motor drive/drive controller – complements the GP-C8. Its advanced motor technology utilizes DC servo motors with remarkable high efficiency allowing the system to be powered by a tiny 9-volt alkaline battery that lasts more than 48 hours! A manual clutch assembly override is convenient to use.

With optional accessories, the GP-C8 easily converts to a computerized telescope.

Standard accessories include a 6x30 Finderscope, Star Diagonal – $1^1/_4$", Visual Back – $1^1/_4$", and a 26mm multi-coated Plössl Eyepiece – $1^1/_4$" (78x). Weight of the complete telescope is 45 lbs.

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For more detailed information on these telescopes, contact a Celestron dealer or Celestron.

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